T-30-68-1
16 FEBRUARY 1968

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CR 151299

INTEGRATED MEDICAL AND BEHAVIORAL LABORATORY MEASUREMENT SYSTEM

PHASE B, SECTION II

FINAL TECHNICAL SUMMARY REPORT

(NASA-CR-151299) INTEGRATED MEDICAL AND BEHAVIORAL LABORATORY MEASUREMENT SYSTEM (IMBLMS), PHASE B. Final Summary Report (Lockheed Missiles and Space Co.) 137 p

N77-78298

Unclas
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LOCKHEED MISSILES & SPACE COMPANY
A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION
SUNNYVALE, CALIFORNIA

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INTEGRATED MEDICAL AND BEHAVIORAL LABORATORY MEASUREMENT SYSTEM

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FINAL TECHNICAL SUMMARY REPORT

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Contract No. NASw-1631-SA1

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IMBLMS

LOCKHEED MISSILES & SPACE COMPANY

A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION

SUNNYVALE, CALIFORNIA

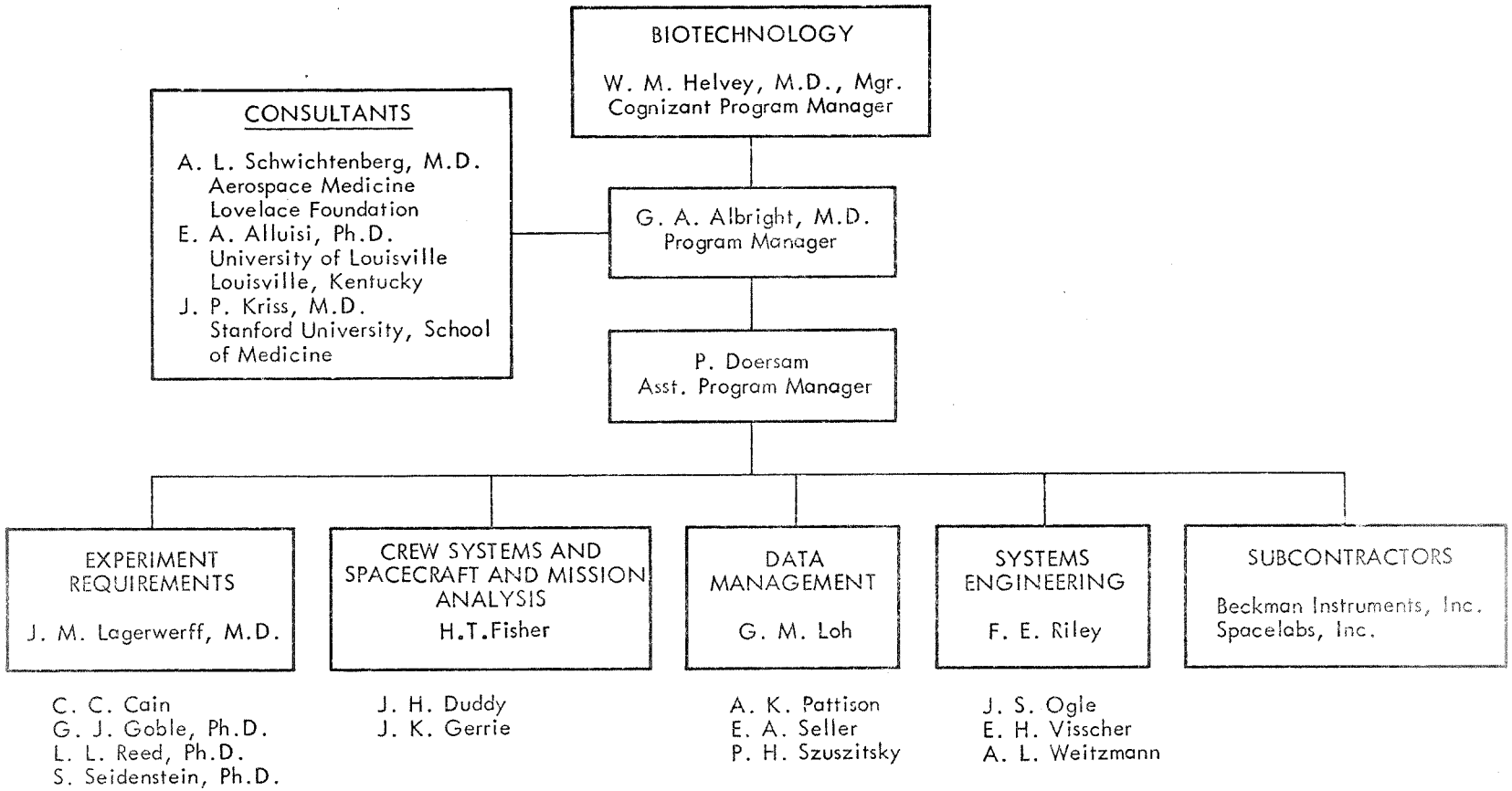
NOTICE

FOREWORD

Lockheed Missiles & Space Company (LMSC) is submitting this final summary technical report to the National Aeronautics and Space Administration (NASA) in compliance with the requirements of NASA Contract NASw-1631, as amended for Phase B, Section II, dated 4 Dec 1967.

This summary volume defines the Integrated Medical and Behavioral Laboratory Measurement System (IMBLMS), identifies measurement groups of the recommended in-flight techniques, analyzes the Apollo Applications Program (AAP) mission and spacecraft aspects of the IMBLMS, illustrates the modular station layouts, presents the individual contributions of the various data management equipment, and describes the IMBLMS design and its supporting engineering documentation. This supporting documentation is presented in the following separate volumes:

Volume I	Measurement Documentation
Volume II	Mission and Spacecraft Analysis
Volume III	Medical and Engineering Reports and Trade Studies



IMBLMS Program Organization – Phase B, Section II

T-30-68-1

ACKNOWLEDGMENTS

This report was prepared by a program team (see preceding page) which comprised members of the Biotechnology organization and R&D support organizations of Lockheed Missiles & Space Company (LMSC), and representatives of Spacelabs, Inc., and Beckman Instruments, Inc. as subcontractors in pertinent physiological and biochemical instrumentation.

Program guidance and review were provided by Dr. W. M. Helvey, Manager, Biotechnology and a group of medical consultants. Appropriate direction was provided by Dr. S. Vinograd, contract monitor for the Office of Manned Space Flight, National Aeronautics and Space Administration (NASA) Washington, D.C., and Mr. Norman Belasco, Crew Systems Division, NASA Manned Space Center, Houston.

The report preparation was accomplished under the direction of Dr. G. A. Albright, IMBLMS Program Manager. The editor was Leon H. Goldich, who was assisted by other members of LMSC R&D Technical Publications.

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Section 1
INTRODUCTION

The objective of the Integrated Medical and Behavioral Laboratory Measurement System (IMBLMS) is the definition, design, development, and flight operation of a flexible biomedical research laboratory for the Apollo Applications Program (AAP) of the National Aeronautics and Space Administration (NASA). The program will accelerate the development and application of technology required for acquiring data to establish a scientific basis for assessing the performance capabilities and limitations of man in undertaking extended space missions. The IMBLMS is designed to be launched in a stowed configuration in a Multiple Docking Adapter and to be translated through the hatches of the Apollo cluster and set up for operation in the Saturn IV-B. The system concept can be easily adapted to pre-installation in a dry-launched S-IVB without sacrificing the system's modular construction or growth capability.

This program dates back to the early 1960's when NASA concern with the safety of astronauts for the relatively short missions of Mercury, Gemini, and Apollo was augmented by a similar concern about man's performance in missions of one year or longer duration. The shorter missions have shown changes in the cardiovascular system, loss of effective blood volume, and loss of calcium and nitrogen from body tissues, and it is likely that these phenomena may be aggravated by longer missions. Such missions therefore will require, in addition to preflight and postflight examination, an extensive on-board measurement capability for early detection of trends and a better understanding of the basic mechanisms involved. Consequently, this program is of major importance to maintaining astronaut safety and well-being during extension of the U.S. manned space program.

The definition of these in-flight measurement capabilities has been the goal of in-house NASA reviews, augmented by extensive industrial studies. NASA has delineated a four-phase IMBLMS program (Ref. 1-1) of which LMSC performed the initial portion –

Phase A Advanced Studies (Biolabs) -- during 1964-1966 (Ref. 1-2), and under which a parallel study is currently being completed by LMSC for the Phase B definition.

These studies, together with the operational experience derived from the Mercury and Gemini programs, NASA and U.S. Air Force biomedical equipment development efforts, and the definition of research needs, have identified requirements and provided the initial capability and direction for development of the IMBLMS. The IMBLMS is now ready to enter an 8-month Phase C Design Activity in accordance with the LMSC Phase C proposal (Ref. 1-3). Phase D, Development and Operation, is planned as a 29-month program leading toward flight operations in 1971.

The IMBLMS approach, as defined during Phase B, will provide a comprehensive flight biomedical measurement capability designed for versatility, flexibility, and growth by the modular grouping of measurement equipment. Space medical authorities generally agree on the range of measurements and available techniques required for in-depth study of the effects of extended spaceflight on man. However, there is less agreement on the priority of these measurements, except for those concerned with safety or clinical monitoring. Experimental measurement priorities are controversial and highly dependent upon future experience, making the establishment of biomedical mission objectives for the early 1970's difficult and subject to continued up-dating. Principal Investigators and NASA ground monitors will insist on altering flight-to-flight biomedical mission objectives, and redirecting the in-flight measurement program as new knowledge becomes available. A modular measurement system designed initially for comprehensive capability will be responsive to these requirements, maximize the use of existing flight-qualified equipment, and permit growth with the incorporation of advances in bioinstrumentation. The definition, approval, implementation, and analysis of biomedical experiments will be expedited since Principal Investigators of the space medical specialties will have most, if not all, of their experimental equipment flight-qualified and integrated into a centralized measurement system. The IMBLMS, modularly configured for each mission, will optimize the use of common equipment and procedures, astronaut/experimenter participation, and data handling of the biomedical experimental program.

The complete IMBLMS design concept consists of 13 modules centralized in a Physiological/Behavioral/Data Management (PBDM) station, an 8-module Biochemical station, and associated peripheral equipment (e.g., ergometer, mass measurement chair, etc.). The PBDM station is capable of performing over 40 measurements as compared with the 17 currently approved, early AAP, in-flight measurements. Figure 1-1 illustrates the systems engineering advantages of the IMBLMS concept as compared with the equipment requirements for the individual flight experiments identified for the early AAP experiments.

The AAP and the IMBLMS provide NASA with the first opportunity for a comprehensive experiment program which will meet the needs of the scientific community and elicit its support in establishing a scientific basis for assessing the performance capabilities and limitations of man in undertaking extended space missions.

LMSC, together with its subcontractors, Beckman Instruments, Inc., and Spacelabs, Inc., has performed the basic studies and analyses that have formed a large part of the foundation and definition of the IMBLMS. This team is now ready to proceed with the design, development, and operation of an Integrated Medical and Behavioral Laboratory Measurement System.

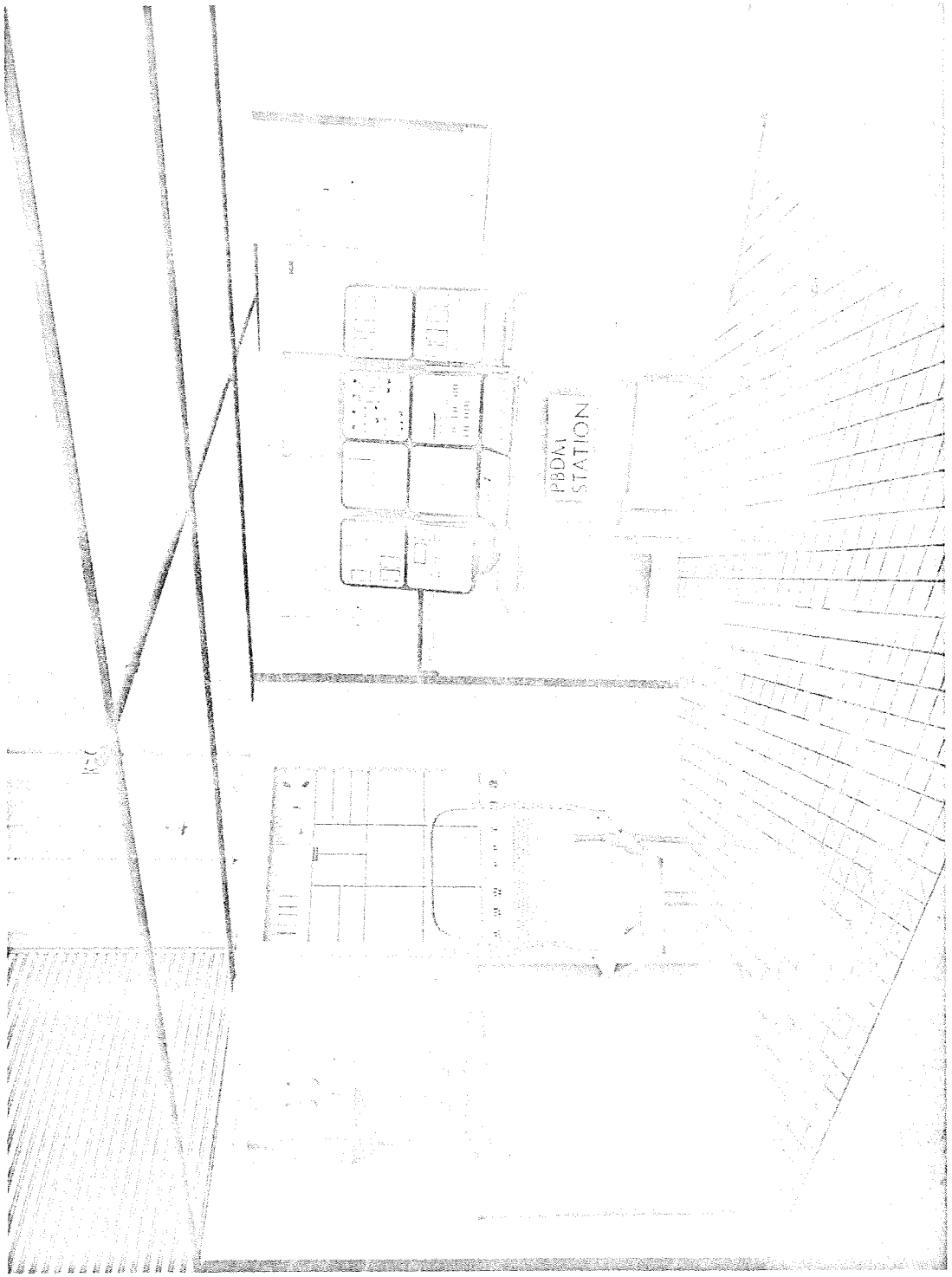

Fig. 1-1 PBDM Station Compared With Early AAD Equipment Packages in S-IVB Experiment Compartment Mockup

Section 2
MEASUREMENT REQUIREMENTS

Under the IMBLMS Phase B, Section II effort, measurement techniques for the physiological, behaviorial, and biochemical elements were reviewed with emphasis on pulmonary function equipment, performance evaluation methods, and the feasibility and simplicity of on-board biochemical measurements. Functional flow diagrams were prepared for all measurements. Requirement allocation sheets (design requirements) and equipment block diagrams were completed for the physiology measurements. Crew requirements, critical environmental parameters, waste management constraints, and measurement module requirements were analyzed for the recommended measurements.

2.1 MEASUREMENT REFINEMENT

The IMBLMS Phase B, Section I effort (Ref. 2-1) resulted in a recommended comprehensive list of biomedical, biochemical, and behavioral measurements, together with the suggested technique or methodology of performing each of these measurements under spaceflight conditions. These recommendations, along with a NASA-furnished list of measurements, were extensively reviewed by the LMSC biomedical team during the Phase B, Section II effort. A comparison of these two lists, together with the results of the final evaluation and recommendations for in-flight measurements, is presented in Table 2-1.

The measurements have been categorized under the eight major body-organ systems. Where appropriate, the clinical laboratory measurements associated with each major group have been listed in a "clinical" subcategory immediately below the major category. The number of in-flight measurements included in each major body organ system is as follows:

- Neurological 7
- Cardiovascular 21

- Respiratory 15
- Metabolic and Nutritional 60
- Endocrinological 7
- Hematological 22
- Microbiological and Immunological 8
- Behavioral 33

Measurements considered for postflight analysis (PFA) require the collection and preservation of periodic biological specimens (e.g., urine, feces, blood, and sweat) for return to Earth in the Command Module (CM). Cryogenic freezing (-70° C to -100° C) is recommended for preserving these samples, although vacuum drying may be necessary for fecal samples and for some urine samples to reduce recovery payloads.

Clinical observation, history, and physical examination constitute an important adjunct. The IMBLMS therefore will provide diagnostic instruments for conducting routine physical examinations, including neurological and behavioral testing. Future growth could include medical treatment and biological research facilities.

2.1.1 Physiological Measurements

The neurological measurements include the capability for conducting the Human Vestibular Function Experiment (M131). Electronystagmograms (ENG) or electrooculograms (EOG) can be recorded during all rotational tests. During electroencephalogram (EEG) sleep-pattern analyses, the concurrent recording of the horizontal channel of the EOG is recommended for rapid eye movement (REM) activity.

The evaluation of cardiovascular and respiratory functions frequently requires the simultaneous recording of various parameters to establish the exact time relationships between these parameters (Table 2-2). For example, a more complete evaluation of the vectorcardiogram, the ballistocardiogram, or the thoracic blood flow requires simultaneous recording of an impedance pneumogram (or other type of spirogram) to determine the portion of the respiratory cycle during which they were recorded.

NASA Meas't. Category	Measurement	Recommendation By: LMSC	NASA	Final LMSC
I	Neurological			
	1. Ocular counterrolling	X[a]	X	X
	2. Linear acceleration threshold	X	–	–
	3. Oculogyral illusion	X	X	X
	4. Visual task with head rotation	X	X	X
	5. Electronystagmogram	X	X	X
	6. Angular acceleration threshold	X	X	X
	7. Cerebral electrical activity	X	X	X
	8. Agravic perception of personal and extrapersonal space	–	X	X
II	Cardiovascular			
	1. ECG	X	X	X
	2. Heart rate	X	–	X
	3. VCG	X	X	X
	4. PCG	X	X	X
	5. VbCG	X	–	X
	6. BCG	X	X	X
	7. Cardiac output	X	X	X
	8. Thoracic blood flow	X	–	X
	9. Arterial blood pressure	X	X	X
	10. Central venous pressure	–	X	X
	11. Periph. venous pressure	X	X	X
	12. Regional blood flow	X	X	X
	13. Arteriolar reactivity	X	X	X
	14. Venous compliance/distensibility	X	X	X
	15. Arterial pulse contour	X	X	X
	16. Response to in-flight exercise	X	X	X
	17. Response to LBNP	X	X	X
	18. Response to leotards	X	X	X
	19. Response to carotid stimulation	X	X	X
	Clinical			
	A. Blood volume	X	X	X
	B. Fluid compartments	X	X	X
	C. Urinary metanephrines	–	PFA[b]	–
	D. Urinary catecholamines	X	PFA	–
	E. Urinary histamines	–	PFA	–
	F. Whole-blood histamines	–	PFA	–
III	Respiratory			
	1. Respiratory rate	X	X	X
	2. Lung volumes	X	X	X
	3. Gas flow rates	X	X	X
	4. Airway resistance	X	X	X
	5. Lung compliance	X	X	X
	6. Alveolar ventilation	X	X	X
	7. Perfusion-ventilation ratio	X	X	X
	8. B/B O_2 consumption and CO_2 production	X	X	X
	9. Continuous O_2 consumption and CO_2 production with exercise	X	X	X
	10. Arterial pO_2	X	–	X
	11. Alveolar/arterial gradient (air and 100 percent O_2)	X	X	X
	12. Diffusion capacity	–	X	X
	Clinical			
	A. Capillary pH	X	X	X
	B. Capillary pO_2	X	X	X
	C. Capillary pCO_2	X	X	X
	D. Whole-blood bicarbonate	–	X	X
IV	Metabolism and Nutrition			
	1. Carbohydrate metabolism	X	–	–
	2. Fat metabolism	X	–	–
	3. Body mass	X	X	X
	4. Muscle size	X	X	X
	5. Muscle strength (EMG)	X	X	X
	6. G-I motility	X	–	–
	7. G-I pressure	X	X	X
	8. G-I pH	X	X	X
	9. Energy metabolism; continuous O_2 and CO_2 analysis with exercise	III[c]	III[c]	III[c]
	10. Oral/ear temperature	–	X	X
	11. Skin temperature (average)	X	X	X
	12. Caloric intake	X	X	X
	13. Fluid intake	X	X	X
	14. Urine volume	X	X	X
	15. Wet weight feces	–	X	X
	16. Return all dried feces	–	X	X
	17. Balance studies			
	Fluids (incl. sweat)	–	X	X
	Nitrogen	–	(e)	–
	Minerals	–	(e)	–
	Electrolytes	–	(e)	–
IV	Metabolism and Nutrition (Cont'd)			
	18. Return all food packages	–	X	X
	19. Bone densitometry	–	X	X
	20. Sweat measurement and sample return	–	X	–
	Clinical			
	A. Total body water	X	X	X
	B. Plasma volume	X	X	X
	C. Urinary creatinine	X	X	X
	D. Urinary nitrogen	–	X	X
	E. Urinary calcium	X	X	X
	F. Urinary phophate	X	X	X
	G. Urinary sodium	X	X	X
	H. Urinary potassium	X	X	X
	I. Urinary chloride	X	X	X
	J. Urinary magnesium	–	X	X
	K. Urinary color	–	X	X
	L. Urinary osmolality	X	X	X
	M. Urinary S. G.	X	X	X
	U. Urinary pH	X	X	X
	O. Urinary glucose	X	X	X
	P. Urinary protein	X	X	X
	Q. Urinary bile	X	X	X
	R. Urinary blood	X	X	X
	S. Urinary sediments	X	X	X
	T. Urinary aldosterone	–	PFA	–
	U. Urinary sulfate	–	X	X
	V. Urinary ketones	X	–	X
	W. Urinary mucoproteins	–	PFA	–
	X. Urinary pyrophosphates	–	PFA	–
	Y. Urinary hydroxyprolines	–	PFA	–
	Z. Urinary total amino acids	–	PFA	–
	AA. Urinary creatine-creatinine ratio	X	–	–
	AB. Whole-blood pH	X	X	X
	AC. Whole-blood pO_2	X	X	X
	AD. Whole-blood pCO_2	X	X	X
	AE. Whole-blood bicarbonate	X	III[c]	X
	AF. Whole-blood uric acid	X	PFA	X
	AG. Whole-blood glucose	X	X	X
	AH. Plasma volume	X	P-P[d]	X
	AI. Plasma total proteins	X	X	X
	AJ. Plasma protein electrophoresis	X	X	X
	AK. Serum sodium	X	X	X
	AL. Serum potassium	X	X	X
	AM. Serum chloride	X	X	X
	AN. Serum calcium	X	PFA	X
	AO. Serum PO_4	X	PFA	X
	AP. Serum phospholipids	X	–	–
	AQ. Serum bilirubin	X	X	X
	AR. Serum cholesterol	X	PFA	X
	AS. Serum BUN	X	PFA	X
	AT. Serum alkal. phosphatase	–	PFA	–
	AU. Serum creat. phosphokinase	–	PFA	–
	AV. Serum LDH	X	X	X
	AW. Serum LDH isoenzymes	–	X	X
	AX. Serum SGOT	X	X	X
	AY. Serum SGPT	X	X	X
	AZ. Serum BSP	X	–	–
	BA. Feces nitrogen	–	(e)	–
	BB. Feces calcium	–	(e)	–
	BC. Feces phosphate	–	(e)	–
	BD. Feces sodium	–	(e)	–
	BE. Feces potassium	–	(e)	–
	BF. Feces chloride	–	(e)	–
	BG. Feces magnesium	–	(e)	–
V	Endocrine			
	Clinical			
	A. Urine aldosterone	–	PFA	–
	B. Urine ADH	X	PFA	–
	C. Urine 17-hydroxysteroids	X	X	(f)
	D. Urine 17-ketosteroids	X	X	(f)
	E. Urine VMA	X	X	X
	F. Urine metanephrines	–	II[c]	–
	G. Urine catecholamines	PFA	II[c]	–
	H. Urine histamine	–	II[c]	–
	I. Urine 5-OH indolacetric acid	–	PFA	–
	J. Urine TSH	–	PFA	–
	K. Urine growth hormone	–	PFA	–
	L. Urine parathormone	PFA	PFA	–
	M. Urine insulin assay	–	PFA	–
	N. Serum T-3 test	X	PFA	X
	O. Serum ADH	–	PFA	–
	P. Serum parathormone	–	PFA	–
	Q. Serum calcitonin	–	PFA	–
	R. Serum glucagon assay	–	PFA	–
	S. Serum free Thyroxin (T-4)	–	PFA	X
	T. Serum TBPA	X	PFA	X
	U. Whole-blood ACTH	–	PFA	–
	V. Whole-blood 17-hydroxysteroids	–	PFA	(f)
	W. Whole-blood histamine	–	PFA	–
	X. Whole-blood 5 OHIAA	X	PFA	–

(a) X = Recommended for in-flight performance
(b) PFA = Postflight analysis on preserved in-flight sample
(c) Same as for NASA category indicated by Roman numeral
(d) P-P = Preflight and postflight only
(e) Conflicts with NASA recommendation indicated under Category IV, Measurement 16
(f) Development recommended; probability of developing acceptable method questionable
(g) Special definitions for NASA Category VIII recommendations as follows:
1 Clinical, 2 Sensory test battery, 3 Perceptual evaluation, 4 Higher thought processes, 5 Memory, 6 Vigilance, 7 Crew intercommunication, 8 Learned activity, 9 Time and motion study

NASA Meas't Category	Measurement	Recommendation By: LMSC	NASA	Final LMSC
IV	Metabolism and Nutrition (Cont'd)			
	18. Return all food packages	–	X	X
	19. Bone densitometry	–	X	X
	20. Sweat measurement and sample return	–	X	–
	Clinical			
	A. Total body water	X	X	X
	B. Plasma volume	X	X	X
	C. Urinary creatinine	X	X	X
	D. Urinary nitrogen	–	X	X
	E. Urinary calcium	X	X	X
	F. Urinary phophate	X	X	X
	G. Urinary sodium	X	X	X
	H. Urinary potassium	X	X	X
	I. Urinary chloride	X	X	X
	J. Urinary magnesium	–	X	X
	K. Urinary color	–	X	X
	L. Urinary osmolality	X	X	X
	M. Urinary S. G.	X	X	X
	U. Urinary pH	X	X	X
	O. Urinary glucose	X	X	X
	P. Urinary protein	X	X	X
	Q. Urinary bile	X	X	X
	R. Urinary blood	X	X	X
	S. Urinary sediments	X	X	X
	T. Urinary aldosterone	–	PFA	–
	U. Urinary sulfate	–	X	X
	V. Urinary ketones	X	–	X
	W. Urinary mucoproteins	–	PFA	–
	X. Urinary pyrophosphates	–	PFA	–
	Y. Urinary hydroxyprolines	–	PFA	–
	Z. Urinary total amino acids	–	PFA	–
	AA. Urinary creatine-creatinine ratio	X	–	–
	AB. Whole-blood pH	X	X	X
	AC. Whole-blood pO_2	X	X	X
	AD. Whole-blood pCO_2	X	X	X
	AE. Whole-blood bicarbonate	X	III(c)	X
	AF. Whole-blood uric acid	X	PFA	X
	AG. Whole-blood glucose	X	X	X
	AH. Plasma volume	X	P-P(d)	X
	AI. Plasma total proteins	X	X	X
	AJ. Plasma protein electrophoresis	X	X	X
	AK. Serum sodium	X	X	X
	AL. Serum potassium	X	X	X
	AM. Serum chloride	X	X	X
	AN. Serum calcium	X	PFA	X
	AO. Serum PO_4	X	PFA	X
	AP. Serum phospholipids	X	–	–
	AQ. Serum bilirubin	X	X	X
	AR. Serum cholesterol	X	PFA	X
	AS. Serum BUN	X	PFA	X
	AT. Serum alkal. phosphatase	–	PFA	–
	AU. Serum creat. phosphokinase	–	PFA	–
	AV. Serum LDH	X	X	X
	AW. Serum LDH isoenzymes	–	X	X
	AX. Serum SGOT	X	X	X
	AY. Serum SGPT	X	X	X
	AZ. Serum BSP	X	–	–
	BA. Feces nitrogen	–	(e)	–
	BB. Feces calcium	–	(e)	–
	BC. Feces phosphate	–	(e)	–
	BD. Feces sodium	–	(e)	–
	BE. Feces potassium	–	(e)	–
	BF. Feces chloride	–	(e)	–
	BG. Feces magnesium	–	(e)	–
V	Endocrine			
	Clinical			
	A. Urine aldosterone	–	PFA	–
	B. Urine ADH	X	PFA	–
	C. Urine 17-hydroxysteroids	X	X	(f)
	D. Urine 17-ketosteroids	X	X	(f)
	E. Urine VMA	X	X	X
	F. Urine metanephrines	–	II(c)	–
	G. Urine catecholamines	PFA	II(c)	–
	H. Urine histamine	–	II(c)	–
	I. Urine 5-OH indolacetric acid	–	PFA	–
	J. Urine TSH	–	PFA	–
	K. Urine growth hormone	–	PFA	–
	L. Urine parathormone	PFA	PFA	–
	M. Urine insulin assay	–	PFA	–
	N. Serum T-3 test	X	PFA	X
	O. Serum ADH	–	PFA	–
	P. Serum parathormone	–	PFA	–
	Q. Serum calcitonin	–	PFA	–
	R. Serum glucagon assay	–	PFA	–
	S. Serum free Thyroxin (T-4)	–	PFA	X
	T. Serum TBPA	X	PFA	X
	U. Whole-blood ACTH	–	PFA	–
	V. Whole-blood 17-hydroxysteroids	–	PFA	(f)
	W. Whole-blood histamine	–	PFA	–
	X. Whole-blood 5 OHIAA	X	PFA	–

NASA Meas't Category	Measurement	Recommendation By: LMSC	NASA (g)	Final LMSC
VI	Hematology			
	Clinical			
	A. Plasma volume	IV(c)	IV(c)	IV(c)
	B. Hematocrit	X	X	X
	C. Hemoglobin	X	X	X
	D. RBC (and morphology)	X	X	X
	E. RBC fragility	X	X	X
	F. RBC survival	X	X	X
	G. RBC mass	X	X	X
	H. RBC enzyme studies	–	PFA	–
	I. Reticulocyte count	X	X	X
	J. WBC (and morphology)	X	X	X
	K. WBC differential	X	X	X
	L. WBC mobilization	X	X	X
	M. Bleeding time	X	X	–
	N. Clotting time	X	X	X
	O. Clot retraction	X	X	X
	P. Prothrombin consumption	X	X	X
	Q. Lymphocyte karyotyping	P-P	X	–
	R. Platelet adhesiveness	X	X	–
	S. Fibrinolytic activity	–	X	–
	T. Blood rheology	–	X	X
	U. Blood lipids	–	X	X
	V. Capillary fragility	–	X	X
	W. Total body water	IV(c)	IV(c)	IV(c)
	X. Blood volume	II(c)	II(c)	II(c)
	Y. Fluid compartments	II(c)	II(c)	II(c)
	Z. Immunoglobulins	X	X	X
	AA. Fibrinogen	X	X	X
	AB. Transferins	–	X	X
	AC. Methemoglobin	X	X	X
	AD. Carboxyhemoglobin	X	X	X
	AE. Platelet count	X	X	X
VII	Microbiology and Immunology			
	1. Body microflora			
	a. bacterial	X	X	X
	b. viral	–	X	(f)
	c. fungal	–	X	X
	2. Environmental culturing			
	a. bacterial	X	X	X
	b. viral	–	X	(f)
	c. fungal	–	X	X
	Clinical			
	A. Immunoglobulins	VI(c)	VI(c)	VI(c)
	B. Fibrinogen	VI(c)	VI(c)	VI(c)
	C. Transferins	–	VI(c)	VI(c)
	D. Hemoglobin	VI(c)	VI(c)	VI(c)
	E. Methemoglobin	VI(c)	VI(c)	VI(c)
	F. Complement titration	–	X	X
	G. Antibody titration	X	X	X
VIII	Behavioral Effects			
	Sensory			
	Acuity	X	2	X
	Depth	X	2	X
	Phorias	X	2	X
	Visual sensitivity	–	2	X
	Auditory thresholds	X	2	X
	Speech perception index	–	2	X
	Psychomotor			
	Arm and hand steadiness	X	9	X
	Wrist and finger speed	X	9	X
	Response orientation	X	–	X
	Arm movement speed	–	9	X
	Multi-limb coordination	X	8	X
	Static strength	–	–	X
	Dynamic strength	–	–	X
	Gross body coordination	X	9	X
	Stamina	–	8	X
	Gross body equilibrium	X	3	X
	Perceptual speed	–	3	X
	Time-sharing	–	6	X
	Response speed	X	8	X
	Movement analysis	–	8	X
	Movement prediction	–	8	X
	Complex processes			
	Adaptive tracking	X	8	X
	Critical task tracking	–	8	X
	Visual monitoring	X	6	X
	Auditory monitoring	X	6	X
	Memory processes	X	5	X
	Mediational processes	X	4	X
	Complex perception	–	3	X
	Work behavior	–	9	X
	Verbal intercommunication	X	7	X
	Operational evaluation reports	–	7	X
	Written communications (logs)	–	7	X
	Debriefing	–	1	X

Table 2-1 Review of IMB LMS Measurements

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DESIRED MEASUREMENTS	REF. ECG, MODIFIED LEAD I	HEART RATE	PHONOCARDIOGRAM	IMPEDANCE PNEUMOGRAM	RESPIRATION RATE	SYSTOLIC AND DIASTOLIC BLOOD PRESSURE	ORAL/EAR BODY TEMPERATURE	AVERAGE SKIN TEMPERATURE
VECTORCARDIOGRAM				X				
PHONO- AND VIBRO-CARDIOGRAM	X			X				
BALLISTOCARDIOGRAM	X		X	X				
SYSTOLIC AND DIASTOLIC BLOOD PRESSURE		X						
THORACIC BLOOD-FLOW/CARDIAC OUTPUT (IMPEDANCE PLETHYSMOGRAPHY)	X		X	X		X		
INDIRECT FICK METHOD/CARDIAC OUTPUT (CO_2 REBREATHING)	X			X		X		
REGIONAL BLOOD FLOW-ARM OR LEG		X				X	X	X
VENOUS COMPLIANCE AND DISTENSIBILITY		X			X	X	X	X
ARTERIAL PULSE CONTOUR	X		X			X		
CENTRAL VENOUS PRESSURE		X			X	X	X	
PERIPHERAL VENOUS PRESSURE		X			X	X	X	
ARTERIOLAR REACTIVITY						X	X	X
CAROTID SINUS STIMULATION	X	X		X	X	X	X	
LBNP EVALUATION	X	X	X	X	X	X	X	X
INFLIGHT EXERCISE EVALUATION	X	X	X	X	X	X	X	X
AVERAGE SKIN TEMPERATURE		X			X		X	
UNSUITED		X			X		X	X
SUITED		X			X		X	
O_2 CONSUMPTION, CO_2 PRODUCTION BREATH BY BREATH AND CONTINUOUS		X		X	X		X	X
ALVEOLAR O_2 AND CO_2		X		X	X		X	X
DIFFUSION CAPACITY O_2		X			X		X	
CAPILLARY pO_2, pCO_2, pH		X			X		X	
ARTERIAL pO_2		X			X		X	
LUNG VOLUMES							X	X
LUNG COMPLIANCE								X
ALVEOLAR – ARTERIAL GRADIENT; AIR AND 100% O_2		X		X	X		X	X

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PARAMETERS TO BE RECORDED														
...NT TEMPERATURE	VECTORCARDIOGRAM	CARDIAC OUTPUT (IMPEDANCE PLETHYSMOGRAM)	CARDIAC OUTPUT (INDIRECT FICK METHOD)	REGIONAL BLOOD FLOW – ARM OR LEG	CENTRAL VENOUS PRESSURE	ARTERIAL PULSE CONTOUR	RELATIVE HUMIDITY	SUIT TEMPERATURE – IN AND OUT	ARTERIAL pO_2 (EAR OXIMETER)	AMBIENT pO_2	AMBIENT PRESSURE	ESOPHAGEAL PRESSURE	ALVEOLAR O_2
								X					
	X		X	X				X					
X	X	X	X	X	X			X					
X	X	X	X	X	X			X					
						X							
						X	X						
									X	X			
								X	X	X			
								X					
								X	X				
										X			
										X	X		
								X					X

Table 2-2 Cross-Correlation Requirements for Physiological Measurements

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Specifying which physiologic measurements are to be recorded simultaneously allows optimization of the electrode/transducer harness configuration, the design of the interface and distribution system module, the location and number of display recording and transmission channel requirements of the data management system, and the location of equipment controls and displays.

The terrestrial pulmonary laboratory uses water-filled spirometers for measuring lung volumes and gas flow rates; diffusion techniques involving carbon monoxide, arterial punctures, and cardiac-catheterization for blood-gas analysis; and whole-body plethysmography for measurements of airway and pulmonary resistance. None of these techniques is considered feasible for space application.

There are two techniques suitable for making IMBLMS pulmonary measurements. The technique using a waterless spirometer is similar to clinical methods now employed and require only developing equipment for the spacecraft environment. However, the equipment is bulky; oxygen replenishment may interrupt measurement; and carbon dioxide removal expendables (1 lb/1 hr) and cooling may be required.

A second technique, using integrating flowmeters and a gas analyzer, offers potential benefits in lighter and more compact equipment. However, its accuracy and clinical acceptance have not been established. Following the derivation by Kisson, McGuire and Sterling (Ref. 2-2):

$$\text{Oxygen consumption} = \frac{1}{p}\int_0^T \phi\left[B_I N_I - B_X N_X\right] \dot{m}_{ax}\, dt$$

where

B_I = ratio of the molecular weight of oxygen to that of expired air

B_X = ratio of the molecular weight of oxygen to that of dry air

ϕ = function of the humidity of the inspired and expired gas and the barometric pressure

N_I, N_X = the mole fractions of oxygen in the inspired air and expired air

The term m_{ax} is the mass flow of the expired air as measured with a mass flowmeter. The multiplications, subtractions, and integration can be accomplished by means of a digital computer.

The pulmonary measurement system shown in Fig. 2-1 employs integrating flowmeters to obtain gas volumes and a mass spectrometer to obtain the partial pressures of oxygen, carbon dioxide, nitrogen, and water vapor. The output of Flowmeter 1 (Fig. 2-1) is integrated by Integrator 1 to derive inspiratory capacity. The output of Flowmeter 2 is integrated by Interator 2 for expiratory reserve capacity, tidal volume, and residual volume.

For measurement of oxygen consumption and breath-by-breath oxygen and carbon-dioxide, a mass spectrometer is used to determine the partial pressure of oxygen, carbon dioxide and water vapor. The inlet and outlet oxygen partial pressures are corrected for humidity in Multipliers 1 and 2, as shown in Fig. 2-1. The oxygen difference is taken in an amplifier, and this difference is multiplied by the mass flow rate of exhaled gas. The product is then integrated by Integrator 2 to give oxygen consumption. Outputs from the mass spectrometer are provided to allow breath-by-breath carbon dioxide production measurement as well as a pN_2 measurement for residual volume determination.

2.1.2 Behavioral Measurements

The behavioral measurement analysis was extended to verify and refine further the measurement profile. A hardware approach was defined which provides a maximum of flexibility in behavioral measurements with a minimum of equipment while still accommodating a wide range of behavioral measurements (e.g., visual, auditory, psychomotor, monitoring, and complex processes).

A revised list of recommended behavioral measurements, based upon the current analysis and equipment system requirements, has evolved from the previous list. A

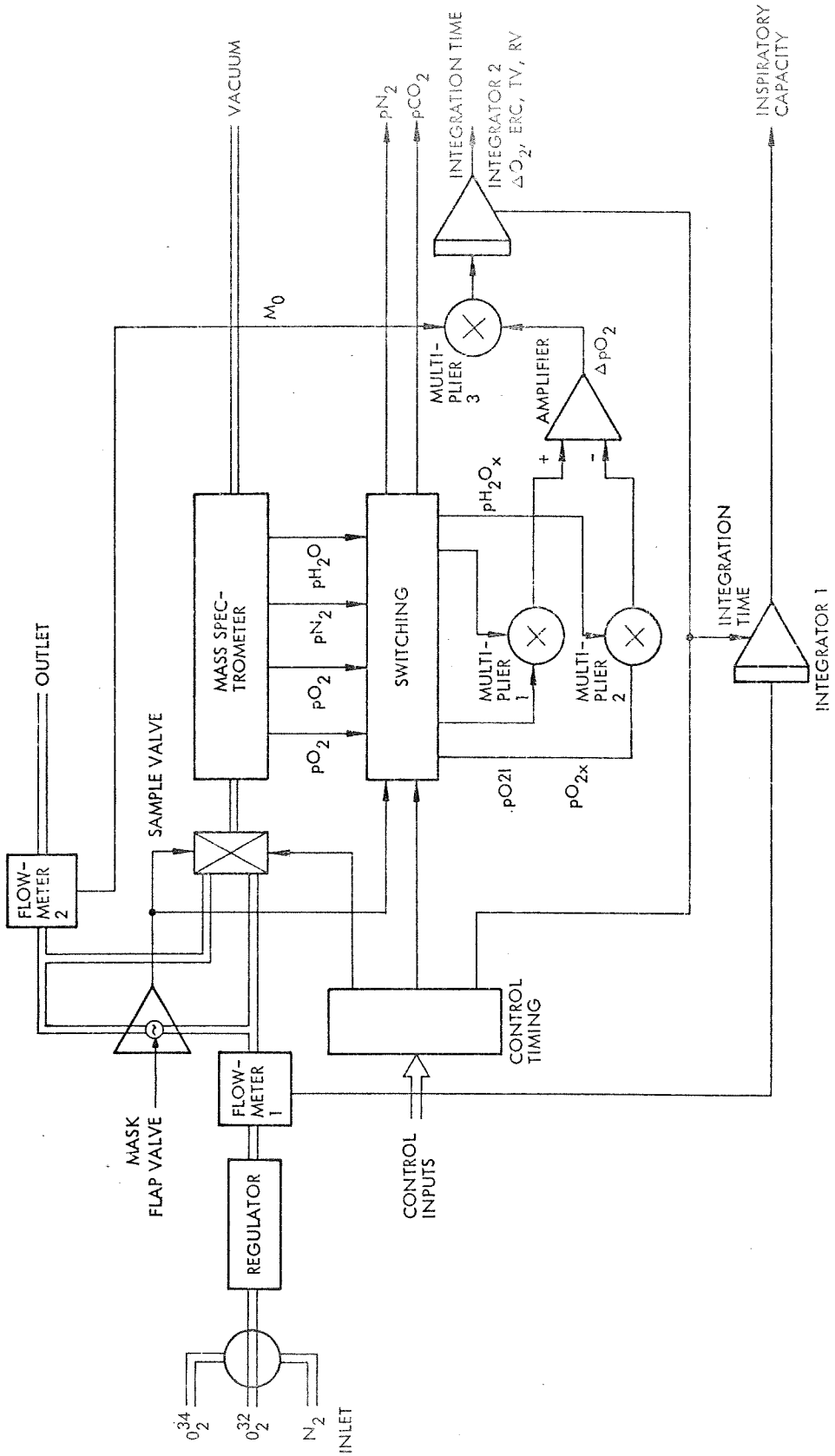

Fig. 2-1 Pulmonary Measurement System

summary of the recommended revised list is presented in Table 2-3. The revisions from the previous analysis include the following:

- Additional visual measurements
- Modification and integration of the psychomotor test battery, in terms of equipment implementation, which permit behavioral measurements to be accommodated through a relatively simple interface. (Measurements of fine manipulation perceptual cognitive behavior monitoring and intellectual processes can be accomplished through a set of signal light and subject response keys. Measurement of continuous control behavior, complex mental processes, and complex perceptual processes can be accomplished through use of a CRT/TV display and a hand controller. The combination of the foregoing elements permits additional measures of fine manipulation, gross positioning, time-sharing, and monitoring.)
- Inclusion of a newly developed technique for assessing complex mental processes, namely, the COTRAN task developed by Alluisi and described in Ref. 2-3
- Measurement of gross motor behavior during the course of physiological testing, because physiological stressing techniques, such as use of a hand dynamometer and bicycle ergometer, are functionally identical to the behavioral test procedure
- Imbedding of psychological tests with other biomedical tests through functional design of the test procedures to yield stimulus – response situations having the requisite behavioral test characteristics on a non-interference basis (e.g., a biochemical measurement and processing task could involve multidisplay monitoring and measurement of response speed, whereas performance of a data processing task could involve memory and mediational processes as well as psychomotor behaviors)

The major results of the Phase B, Section II, effort in the refinement and extension of previous measurement recommendations and implementation methodology are as follows:

- Measurement selection has been further verified against a composite rationale of relation to operational function; operational, technical, and scientific utility; and derivation from developed behavioral test techniques.

Table 2-3

SUMMARY – RECOMMENDED REVISED BEHAVIORAL MEASUREMENTS

Major Category	Subcategory	Description of Measurement		IMBLMS Behavior Measurements	Candidate for Imbedding	Measured From Mission Operations
SENSORY MOTOR	Visual	Acuity		X		
		Depth perception		X		
		Phorias, muscle balance		X		
		Visual field		X		
		Visual sensitivity		X		
	Auditory	Pure tone threshold		X		
		Speech intelligibility index		X		
	Psychomotor	Fine Motor Abilities	Arm and hand steadiness	X	X	X
			Wrist and arm speed	X	X	X
		Gross Positioning Abilities	Response orientation	X	X	X
			Arm-movement speed	X	X	X
			Multilimb coordination	X	X	X
		Gross Body Movement	Static strength			X
			Dynamic strength			X
			Gross body coordination			X
			Gross body equilibrium			
			Stamina			X
		Continuous Control	Movement analysis	X		
			Movement prediction	X		
			Adaptive tracking	X		
			Critical task tracking	X		
		Perceptual. Cognitive	Perceptual speed	X	X	
			Time-sharing	X	X	
			Response speed	X	X	
COMPLEX BEHAVIOR	Monitoring	Visual monitoring		X	X	X
		Probability monitoring		X	X	X
		Auditory monitoring		X		X
	Complex Mental Processes	Memory processes		X		
		Mediational processes		X		
	Complex Perceptual Processes			X		
	Work Behavior				X	X
INDIVIDUAL AND INTERPERSONAL BEHAVIOR	Open Verbal Communication					X
	Written Communication					X
	Operational Evaluation Reports					X
	Debriefing Reports					X

- Flexibility of the measurement approach has been assured through selection of a variety of measurement techniques, and through their implementation as separate behavioral measures, measures obtained through the design of IMBLMS tasks (imbedding), and measures of performance of other IMBLMS tasks on a noninterference basis.
- The complexity of performance measurement hardware has been reduced through flexible computer programming and increased hardware and procedure commonality.
- The number and specification of measures has been increased.
- Each measurement has been defined in terms of its functional characteristics, the method employed and the hardware technique ordinarily used to obtain the measurement.
- Behavioral measures will be derived from required astronaut performance of physiological test procedures.
- Individual and interpersonal behavior will be assessed through the study and analysis of records of normal operational and communication procedures.

This effort has yielded a comprehensive behavioral test element capable of sampling a wide variety of behaviors which utilize a set of developed techniques. Through computer programming this flexibility is afforded with a minimum of hardware.

The overall behavioral measurement approach makes use of other IMBLMS biomedical tasks to provide a substantial augmentation of measurement capabilities. However, it is always possible to perform behavioral measurement through the behavioral test module independent of the other IMBLMS tasks.

2.1.3 Biochemical Measurements

The use of automated biochemical procedures for the IMBLMS was compared with manual methods. For the clinical laboratory the automated procedures are superior to manual analysis in that large numbers of the same test may be performed with a

relatively high degree of freedom from operator mistakes. In the IMBLMS, however, a maximum of three analyses of the same type will even be required on the same day or even the same week. Consequently, the full capability of automation cannot be realized. Of the various types of automated chemical analyzers in existence today, none is capable of complete sample processing; they can perform only the simplest types of test; and all require large reagent reservoirs. In addition to the engineering problems anticipated in adapting presently available automated tests to spacecraft environments, or in automating new tests, the cost of this development would be excessive. For even a simple test, such as determining the refractive index of urine, development of an automated procedure probably would cost at least 500 times the amount required to develop a manual version. Further, the reliability of an automated analyzer could be expected to be considerably less than desirable.

All the biochemical measurement techniques recommended for the IMBLMS in this phase of the program may be classified as manual types. They differ from ordinary manual testing, however, in that the majority of the manipulations are done before lift-off and are not performed by the astronaut. Single-use test packets with premeasured reagents are proposed for the majority of the tests. Sample measurement will be performed by the simple expedient of filling a capillary tube. This concept minimizes the possibility of astronaut error and also eliminates the possibility of spilling the contents of large reagent containers. This handling concept should provide just as accurate and rapid results as automated procedures, but with greater flexibility and reliability.

The biochemical measurements (Table 2-4) are grouped according to the basic technique employed, and are rated according to their clinical importance and development feasibility.

The basic instruments used for these tests are not expected to create any inordinate development problems. However, the development of ancillary equipment and test techniques for the large number of determinations is a major task. It is recommended that laboratory verification of space-applicable techniques in each of the major equipment categories be conducted during the Phase C effort to establish basic handling technology and instrument requirements.

Table 2-4

BIOCHEMICAL/ MICROBIOLOGICAL MEASUREMENTS—DEVELOPMENT SUMMARY

Measurement	Measurement Development Evaluation[a]	Measurement	Measurement Development Evaluation[a]
Test Tapes		Colorimetry (Cont.)	
pH	5	Serotonin	3
Protein	5	Creatine	3
Glucose	5	Sulfate	3
Blood	5	Magnesium	3
Uric acid	5	Blood lipids	3
BUN	5	Bicarbonate	3
Ketones	5	Hydroxyprolines	2
Bilirubin	5	Phospholipids	2
Color	5	17-hydroxysteroids	2
Bile	5	17-ketosteroids	2
Miscellaneous		Catecholamines	2
Urinary refractive index	5	Parathormone	2
Hematocrit	5	Aldosterone	0
Bleeding time	5	RBC enzymes	0
Clotting time	5	5-OHIAA	0
Capillary fragility	4	Histamine	0
Antibody titration	4	Mucoproteins	0
Total body water	4	Pyrophosphates	0
Prothrombin time	3	Amino acids	0
Prothrombin consumption	3	ADH	0
Blood rheology	3	ACTH	0
T-4	3	Metanephrines	0
Specific clotting elements	0	CPK	0
Fibrinolytic activity	0	Alkaline phosphatase	0
TSH	0	Microscopy	
Growth hormone	0	RBC & WBC morphology	5
Parathyroid hormone	0	Urinary sediments	5
Insulin assay	0	WBC differential	5
Glucagon assay	0	Body microflora	4
Calcitonin	0	Environmental microflora	4
Electrophoresis		WBC count	4
Immunoglobulins	4	Platelet count	4
Serum proteins	4	Reticulocyte count	3
LDH isoenzymes	4	Leucocyte mobility	2
Plasma proteins	4	Lymphocyte karyotyping	2
Hemoglobin	4	Platelet adhesiveness	2
Methemoglobin	4	Ion-Specific Electrodes	
Complement titration	3	pH	5
VMA	3	Sodium	5
Transferins	3	Potassium	5
Colorimetry		Chloride	4
Calcium	5	Carbon dioxide	4
Hemoglobin	5	Oxygen	4
Bilirubin	5	Incubator	
RBC fragility	5	Bacterial culturing	4
Creatinine	4	Clot retraction	4
Phosphates	4	Fungi	4
Proteins (total)	4	Virus	3
Glucose	4	Radiochemistry	
LDH	4	T-3	4
SGOT	4	TBPA	3
SGPT	4	RBC mass	1
Carboxyhemoglobin	4	RBC survival	1
Nitrogen	3	Plasma volume	1
Fibrinogen	3		
Cholesterol	3		

(a) Level of Evaluation:
- 5 Highly significant; moderate development effort
- 4 Moderately significant; moderate development effort
- 3 Less significant or extensive development effort
- 2 Major technological advancement required
- 1 Possible creation of health hazard
- 0 Sample storage required for postflight analysis only

Certain biochemical determinations require major technological advances in earth-based methodologies before they can be used in space. The steroids and hormones require laborious extractions and purifications. Karyotyping, leucocyte motility, platelet adhesiveness, and phagocytosis activity require a high degree of skill and training using presently known methods.

Table 2-5 represents a representative measurements frequency schedule for a typical mission of 56-day duration. The various major measurement groups have been subdivided into two or more subgroups, in order to accomplish a better spread of astronaut activities throughout the flight, based on a 6-day work week.

Measurement performance in accordance with this frequency schedule will require various expendable items, such as syringes, unopettes, plastic bags, etc., which will weigh approximately 45 lb and require a volume of 1 ft^3. Three 24-hr urine aliquots are to be collected from each astronaut every week and, in order to permit performance of all required postflight analysis, the total preserved aliquot volume should be 40 to 50 ml. LMSC recommends that the number of venipunctures for obtaining blood samples be limited to one every 2 weeks. The comprehensive on-board hematological measurements have been scheduled to coincide with these venipunctures, thus allowing the on-board tests to be performed with the same samples preserved for postflight analysis. Each on-board and preserved sample requires 30 ml of blood.

On the basis of approximately (1) 0.05 lb weight and 5 $in.^3$ volume for each 24-hr urine aliquot and each venous blood sample, (2) a dried fecal output of 0.12 lb/man/day with a volume of 5 $in.^3$, and (3) sweat samples of 0.01 lb weight and 0.5 $in.^3$ volume each, the total weights and volumes of the returned biological samples for a 56-day flight, including the storage bags, will amount to 24.5 lb and 1,272 $in.^3$.

2.2 FUNCTIONAL FLOW DIAGRAMS

The initial engineering documentation step was the establishment of an accurate and complete functional base for all recommended IMBLMS measurements. This was

Table 2-5

IMBLMS MEASUREMENTS FREQUENCY SCHEDULE FOR TYPICAL 56-DAY MISSION

NASA Category	Measurement	Mission Days							
		1	8	15	22	29	36	43	50 R[a]
I	NEUROLOGICAL								
	Semicircular canal tests		X		X		X		X
	Spatial location tests		X		X		X		X
	EEG recording		X X X		X X X		X X X		X X X
II	CARDIOVASCULAR								
	Routine dynamic monitoring	X	X	X	X X	X	X X	X	X X
	Vascular dynamics	X		X		X		X	
	Provocative tests				X		X		X
III	RESPIRATORY								
	Mechanics	X		X		X		X	
	Gas/blood exchange	X	X	X	X	X	X	X	X
IV	METABOLISM AND NUTRITION								
	Fluids/solids intake/output (V;M)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
	Body mass, muscle size and strength	X	X	X	X	X	X	X	X
	Body water, plasma volume	X	X	X	X	X	X	X	X
V	ENDOCRINE								
	(See Category IX)								
VI	HEMATOLOGY								
	(See Category IX)								
VII	MICROBIOLOGY AND IMMUNOLOGY								
	Body microflora	X		X		X		X	X
	Environmental culturing	X		X		X		X	X
VIII	BEHAVIORAL EFFECTS								
	Sensory acuity (visual and auditory)	X	X		X	X		X	X
	Psychomotor	X	X X	X	X X	X X	X X	X X	X X
	Complex processes	X	X X	X	X X	X X	X X	X X	X X
	Time and motion	X	X		X	X	X		X
IX	CLINICAL BIOCHEMISTRY								
	Urinalysis								
	Routine	X X	X X	X X	X X	X X	X X	X X	X X
	Cardiovascular and respiratory	X		X	X		X		X
	Metabolism and nutrition	X		X		X		X	X
	Endocrine	X		X		X		X	X
	24-hr sample preservation	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X
	Blood Analysis								
	Routine hematology	X	X X	X	X X	X	X X	X	X X
	Cardiovascular and respiratory	X		X		X		X	
	Metabolism and nutrition	X		X		X		X	
	Endocrine	X		X		X		X	
	Comprehensive hematology	X		X		X		X	
	Immunology	X		X		X		X	
	Sample preservation	X		X		X		X	X

(a) R – Reentry

(b) Performed during flight whenever applicable; includes wet fecal weight measurement and drying of all feces for postflight analysis

accomplished by means of functional flow diagrams – a graphic presentation of the actions to be performed in sequential order in the evolution of the IMBLMS measurement requirements.

The functional approach ensured that the definition occurred on a total system basis with full recognition of all involved principles, provided a means of relating the functions to hardware, and established a clear frame of reference for requirements to be used for communication between the Principal Investigators, the equipment developers or suppliers, the integration contractor, and NASA.

Figures 2-2, 2-3, and 2-4 illustrate the relationship of the physiology element to the overall IMBLMS and, through the development of successive indenture levels, demonstrate the flow sequence from system level to a group of functions concerned with individual measurements. Three categories of measurements fall within the Physiological Measurements (Fig. 2-2, Function 1.2). One of these categories, Cardiovascular Measurements (Fig. 2-3), comprises three groupings of measurements. One of these measurements is to evaluate cardiac dynamics (Function 1.2.2.1) which is shown in Fig. 2-4. This functional flow diagram illustrates the sequential actions necessary to accomplish each of the nine measurements concerned with cardiac dynamics.

2.3 REQUIREMENTS ALLOCATION SHEETS

The medical/engineering design requirements are established by means of the Requirements Allocation Sheets (RAS), which are based on and numerically identified with the functional flow diagrams.

The RAS contains an analysis of each function or group of functions depicted on functional flow diagram. It is the key document for identifying and allocating requirements for equipment by establishing the relationship of each function and its corresponding design requirements, including design constraints, crew requirements, environmental constraints, and interfaces with the spacecraft and other equipment. Table 2-6 (for Function 1.2.2.1.1) is illustrative of the Requirements Allocation Sheet documentation

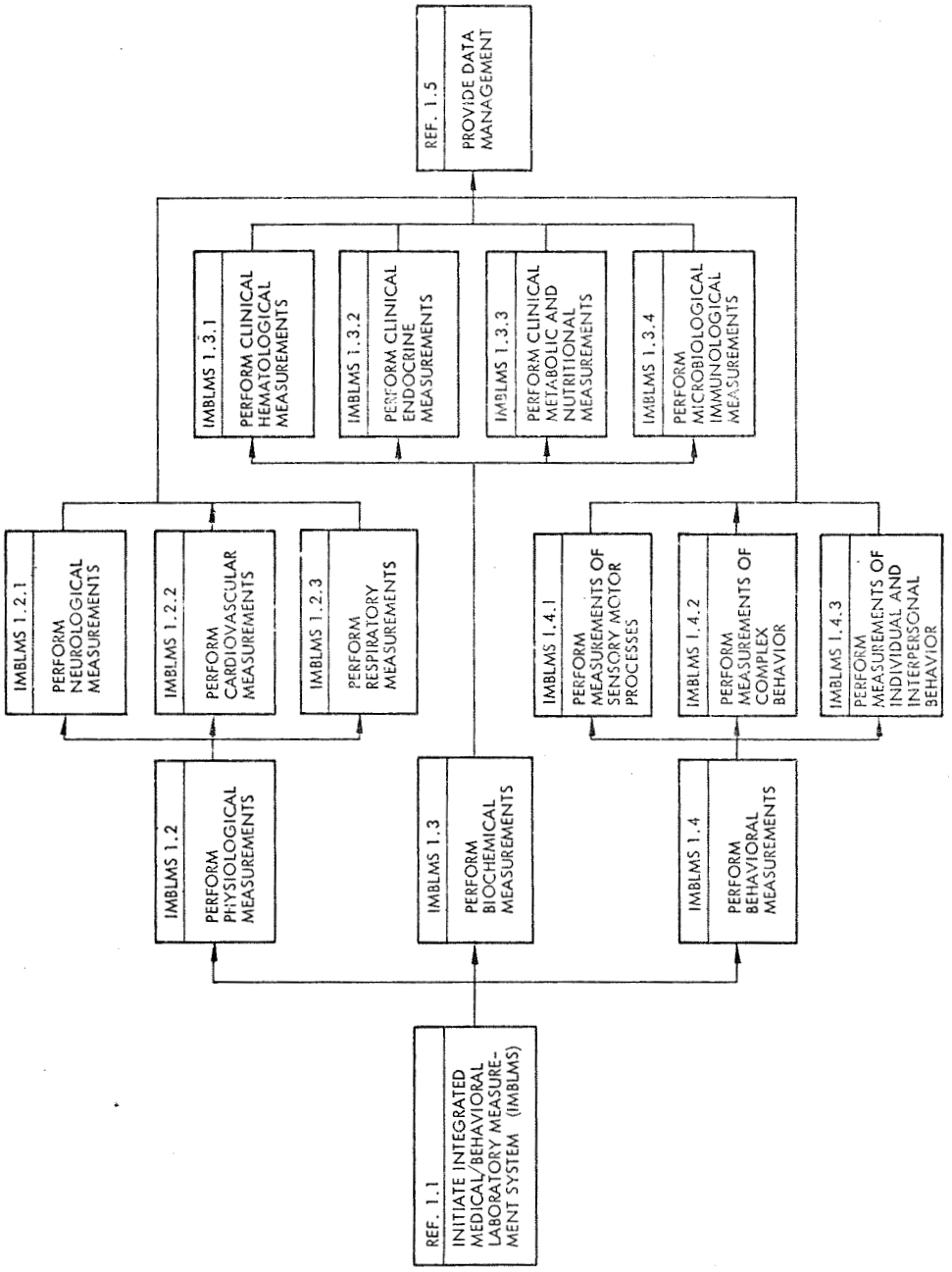

Fig. 2-2 Initiation of Integrated Medical and Behavioral Laboratory Measurement System – Function 1.1

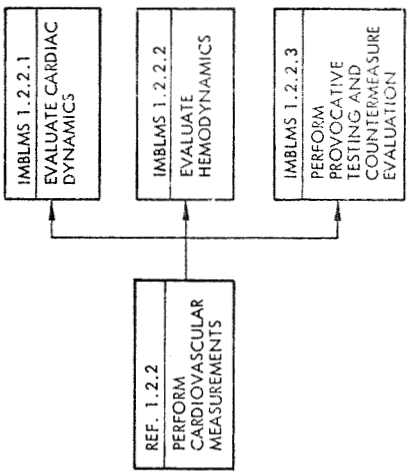

Fig. 2-3 Performance of Cardiovascular Measurements – Function 1.2.2

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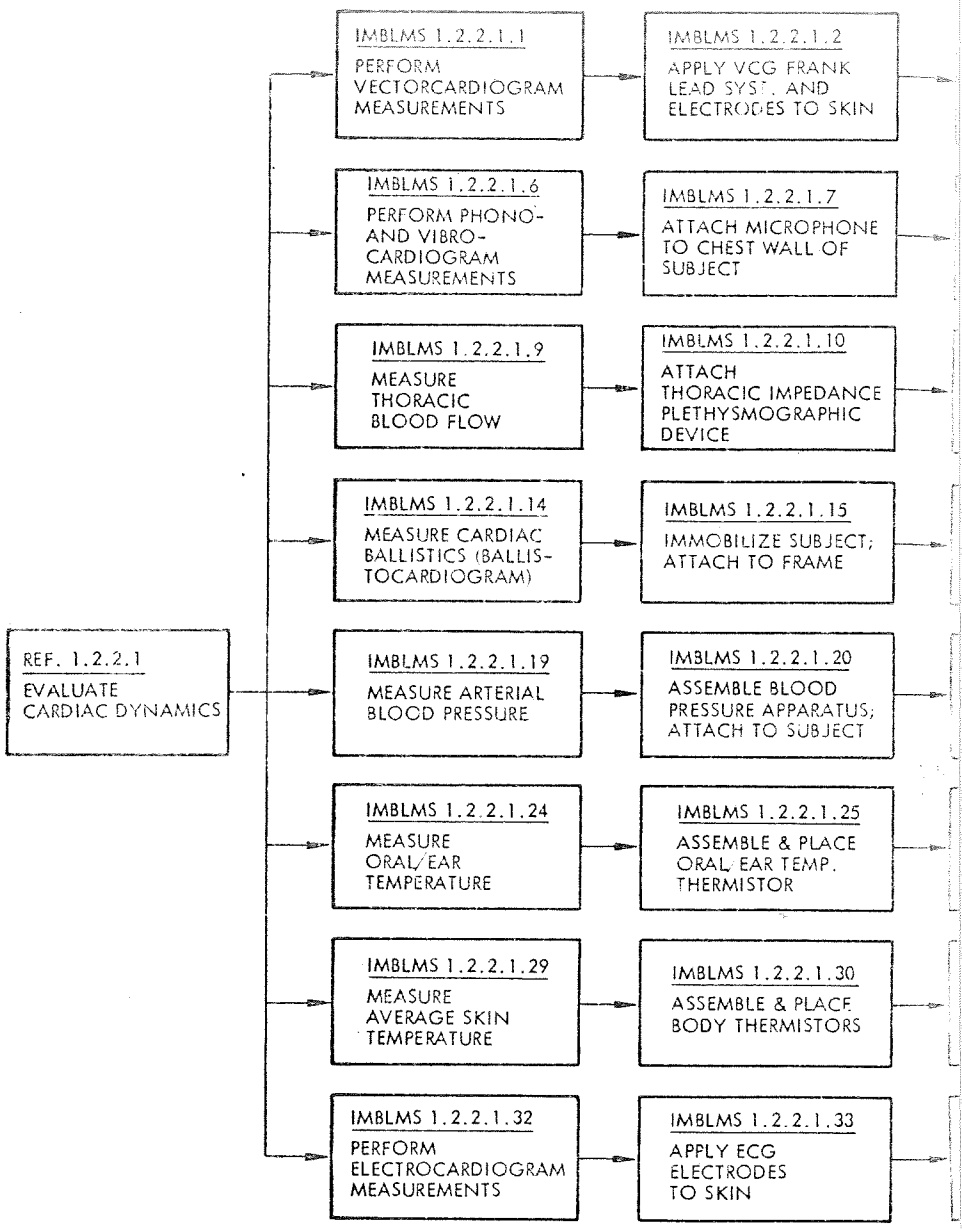

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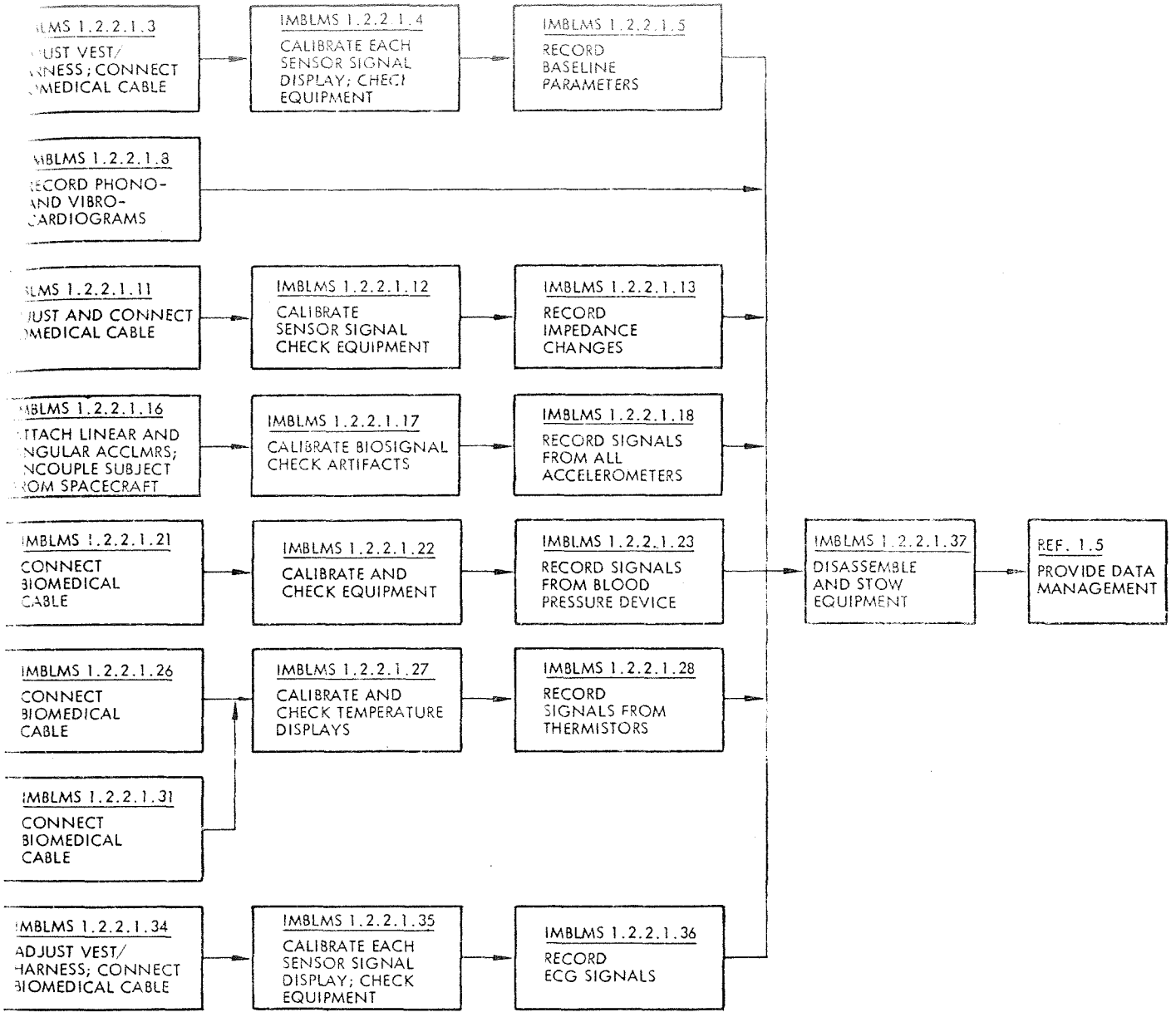

FUNCTIONAL FLOW DIAGRAM – FUNCTION NO. 1.2.2.1

Fig. 2-4 Evaluation of Cardiac Dynamics – Function 1.2.2.1

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Table 2-6

REQUIREMENTS ALLOCATION SHEET – PERFORMANCE OF VECTORCARDIOGRAM MEASUREMENTS (Task 1.2.2.1.1)

Functional Number and Name	Design Requirements
1.2.2.1.1 – PERFORM VECTORCARDIOGRAM (VCG) MEASUREMENTS	(1) Description of Function The stresses of spaceflight will probably produce changes in cardiac function which are reflected in the electrical potentials measured at the body's surface. The vectorcardiogram, using the Frank orthogonal lead system, furnishes data which can be reduced and analyzed by computer techniques. By recording the vectorcardiogram at various intervals during spaceflight – under resting conditions and after standardized exercise – and again after return to Earth, it is hoped to identify and to quantitate, to some degree, the changes in cardiac electrical activity that result from weightlessness and other stresses of spaceflight. From the three voltages recorded simultaneously by body surface electrodes placed in the three major axes of the chest, the following VCG items will be completed: • Spatial mean vectors of QRS, T, ST, ventricular gradient, angle between the spatial QRS vector and the T vector • Instantaneous P, QRS, and T vectors • Heart rate and rhythm • PR interval, QRS duration, QT interval • First derivative of ECG waveform • Special parameters to be used in the statistical analysis (2) Description of Measurement System Spatial vectorcardiography is a method for determining the three orthogonal components of the human heart dipole. It is expected that the measurement will detect changes, if any, in the location of the heart dipole due to long-term exposure to zero-g conditions. The VCG measurement system consists of an electrode harness assembly (using eight electrodes), a Frank VCG resistor network, an automatic calibration system, and three ECG signal conditioners. The Frank lead network is used to minimize the number of electrodes required, consistent with operating stability and reduction of noise and motion artifact. The Frank lead electrode arrangement is such that five electrodes are arranged in a transverse plane at the auxiliary midline on the left lateral chest, sternum, back, and the left anterior chest wall, respectively. A sixth electrode is placed at the back of the neck, and a seventh at the mid-posterior waist-line. A common electrode is normally used on the right anterior chest wall. Noise at the input must be less than 10 μv peak-to-peak within the band of 0.2 to 100 Hz. The gain is continuously variable from 1,000 to 4,500. The signal conditioner has a manually operated calibration switch which inserts a 1-mv pulse signal at the input. The vectorcardiogram will be displayed on a CRT equipped with Z-axis modulation, and recorded on the biomedical recorder for transmission to the ground. (3) Description of Equipment • Electrodes: Standard NASA type, 8 required, 3.2-gm weight (ea.) • Harness (under development): Estimated weight less than 5 lb

Functional Number and Name	Design Requirements
1.2.2.1.1 – PERFORM VECTORCARDIOGRAM (VCG) MEASUREMENTS (Cont'd)	• Signal conditioners: 3 required, 45-gm weight (ea.) • Ergometer (on-board for other experiments) • Power: 1w • Electrode preparation kit • Frank resistor network and calibration unit (4) Design Characteristics • Electrodes – Standard Apollo body work electrodes may be utilized for this measurement. – Electrode harness assembly must be stored near use location. – Identification and unstowing assembly should not require more than 10 sec. – Electrodes should be held firmly in proper location without mechanical or chemical irritation of the skin. – Electrodes must not introduce electrical noise into the signal. • Harness and Vest – A body-worn vest, with built-in harness to connect the five electronic modules and electrodes properly to the power source, is under development for Experiment M093 – Vectorcardiogram. Weight is less than 5 lb. • Pertinent Characteristics – Common mode rejection: 80 db – Output impedance: 200 ohms or less – Output characteristics: 0 to 5v with respect to ground, biased 2.5v – Frequency response: ±3 db from 0.2 to 100 Hz – Noise: Less than 10 μv referred to the input – Size: 5 modules (1.5 by 2.3 by 0.410 in. -ea.) – Total weight: Less than 300 gm (excluding electrodes and harness) (5) Spacecraft Interface Requirements • Mounting provisions must be provided for stowed equipment during launch. • Stowage provisions must be provided during in-flight periods when the equipment is not in use. (6) Interface With Other Equipment • The ergometer will be used with this measurement. • Power subsystem and data management subsystem support will be required. • The sensor signal should be displayed on a CRT. • Parameters will be as follows: – Temperature: 0° F to 160° F – Pressure: 15.5 to 1.47×10^{-5} psia – Humidity: 15% to 95%

Table 2-6 (Cont'd)

Functional Number and Name	Design Requirements
1.2.2.1.1 – PERFORM VECTORCARDIOGRAM (VCG) MEASUREMENTS (Cont'd)	– Oxygen (atmosphere): 100% at 5.5 to 7.5 psia – Acceleration: ±15 g for longitudinal axis, 7.25 g for other axes – Vibration: 12.6 g rms, random vibration, 3-axis – Acoustic noise: 135 db overall sound pressure level (7) Data Measurement Requirements • Unit average range tolerance: 0 to 2.5 v ECG signal, biased at 2.5 v ± 0.25 v • Frequency time unit duration: ECG signals from 0.2 to 100 Hz passband amplifier • Number of channels: three • Functions: Transmission and recording (8) Engineering Summary • Weight: 5 lb • Dimensions: 6 by 22 by 12 in. • Power consumption: 1 w • Input to electrodes – Range: 0 to 2 m – Number of leads: 7 or 8 • Output from signal conditioners – Range: 5 v/ 200 ohm – Frequency response: 0.2 to 100 Hz – Number of channels: 3 • Calibration required: Integral, 1 mv • Accuracy/sensitivity: ±5% • Computation required: N/A • Signal conversion to digital form: Standard • Time required for one reading: 15 to 30 sec • Simultaneous measurements: ZPN • Display requirements: CRT monitor • Control requirements: 3-position switch • Monitor/alarm required: N/A • Recording requirements: Yes

prepared for the physiology element during this study effort. As the IMBLMS design evolves, RAS data and information will be expanded to reflect the detailed engineering data on schematic block diagrams, design sheets, and specifications.

2.3.1 Crew-Oriented Requirements

The astronaut/experimenter must be trained to identify, retrieve, assemble, and operate all major equipment items and provocative test assemblies, together with their appropriate auxiliary equipment, including the attachment of electrodes and transducers to the proper sites on the body. He must be able to monitor the various signals on the displays, determine if the signals are recording properly and, where necessary, make equipment adjustments and calibrations. The techniques of handling and preparing the various specimens, utilization of the instruments, and assessment of the appropriateness of the recorded test results pertaining to the biochemical measurements will require training to the level of a laboratory technician.

Use of the telemicroscope would reduce the training level required for microscopic examinations of blood and urinary sediments and provide ground observer near real-time images for more detailed study. Certain provocative tests, such as the application of lower body negative pressure (LBNP) may require the presence of an astronaut/physician. A physician crew member will reduce the training requirements for the other astronauts. The IMBLMS on-board data display and computation capability will permit the astronaut/physician to assume a more important role in relationship to ground-based Principal Investigators, by means of on-board data evaluation, compression, and in-flight redirection of the experimental program.

2.3.2 Waste Management Requirements

The method used for the collection of urine must be hygienically acceptable, with each astronaut having his own urinal. The urine samples to be taken for on-board analysis, and those to be preserved for postflight analysis must be uncontaminated, undiluted, and free of additives which might interfere with the accuracy of these analyses.

If a common receptacle is used in the urine volume measurement device, it should be provided with a rinsing system to prevent bacterial growth and accumulation of urinary salts. Aliquots of 24-hr urine samples should be frozen rather than vacuum-dried for more accurate postflight analysis. Similarly, the "weighing" of moist fecal specimens requires individual collection and subsequent individual vacuum drying for postflight analysis.

2.3.3 Critical Environmental Parameters

The environmental parameters are usually considered along with the life-support system and include cabin pressure; temperature; humidity; concentrations of carbon monoxide, carbon dioxide and other contaminants in the cabin atmosphere; radiation level; acceleration; noise, and vibration. These parameters provide the earliest indication of the existence of unacceptable conditions in a habitable environment and are an important consideration in the interpretation of biomedical experimental data. Certain biomedical procedures, (e.g., pulmonary function studies and exercise evaluation) require a more accurate measure of environmental parameters, such as cabin pressure and temperature, than normally provided by the vehicle life-support monitoring system. A summary analysis of the critical environmental parameters is presented in Table 2-7.

The Requirement Allocation Sheets will identify these additional environmental sensor requirements (e.g., cabin temperature and pressure, O_2 and CO_2 concentration, and water vapor pressure) for inclusion in IMBLMS.

2.3.4 Measurement Modular Requirements

The design of a flexible and modular IMBLMS requires definition of the scope or comprehensiveness of the system and the development of logical groupings of measurements by commonality and sophistication of function and purpose. A basic function of IMBLMS, in addition to providing experimental capability, is to ensure the safety and well being of the astronauts. Table 2-8 categorizes the anticipated effects of extended

Table 2-7

CRITICAL ENVIRONMENTAL PARAMETERS

Environmental Parameter	Remarks	Priority
Cabin Temperature	Wide variations about OWS possible	1
Cabin Pressure	On-board gross system monitor present	1
Cabin O_2 Concentration	Affects respiratory evaluations	2
Cabin CO_2 Concentration	Affects respiratory evaluations	1
Cabin H_2O Vapor Pressure	Affects thermodynamics during exercise	1
Contaminants	Primarily safety consideration	3
Radiation	Primarily safety consideration	3
Surface Temperature	Alone, not pertinent to IMBLMS	3
Noise	Not anticipated to be a problem	3
Acceleration	On-board system provides data	3
Vibration	Not anticipated to be a problem	3

1 Nonavailability could affect value of certain IMBLMS measurements

2 Less effect on IMBLMS measurements than Priority 1 items

3 IMBLMS measurements not affected or obtained by suitable accurate spacecraft systems

Table 2-8

CLINICAL MONITORING CAPABILITY

Effect or Status	Measurements	Equipment
General Health	History and physical examination signs, caloric and fluid intake, body mass, and urinalysis	Mass measurement, refractometer, test tapes, microscope, and urine volume measurement
Cardiovascular Effects of Weightlessness	Physiological measurements during provocative testing and stress monitoring – BP, HR, RR, and temperature	Ergometer, LBNP, ECG, impedance pneumogram, BP apparatus, thermistor, and displays
Environmental Effects		
Radiation and Oxygen Toxicity	Hematological measurements – Hb, WBC, and differential count	Staining and counting apparatus, microscope, and colorimeter
Microbial Contamination	Microbiological culturing – bacterial and fungal	Incubator and microscope
Chemical Contamination	Pulmonary function studies – timed vital capacity	Integrating pneumotachometer
	Liver, renal and CNS functions – bilirubin, urinalysis, and EEG	Colorimeter and EEG
Interpersonal Relationships	Performance measurements – verbal analysis	Communication
Musculoskeletal Effects of Weightlessness	Metabolic measurements – urinary calcium	Colorimeter

spaceflight and tabulates the measurements and equipment required for safety or clinical monitoring of the astronauts. These equipment requirements form the basis for initial modular grouping. Specific mission requirements such as the synchronous orbit, where hematological effects of radiation exposure are of principal concern, provide additional constraints. The desirability of grouping measurement capability by major body organ systems influenced the modular assignment of the clinical monitoring equipment to facilitate the logical addition of experimental equipment. Data management equipment was centralized and grouped by increasing capability to meet the greater needs of the comprehensive measurements and to complement the skills of the astronaut/experimenter. The allocation of measurement functions to modules based on human factors considerations, equipment installation volumes, envelopes, and panel area constraints are discussed in Section 3 of this volume. The grouping of major organ system equipment as discrete modular and submodular entities permits extensive experiment investigation of one or more organ system consistent with AAP mission objectives and spacecraft constraints, and will permit future growth, substitution, or modification as required for later experiments.

2.3.5 Engineering Documentation

The documentation required will vary considerably, depending upon the development status of the equipment that will satisfy the medical/engineering requirements. As soon as the documentation effort has identified each element of the IMBLMS system, a decision must be reached regarding the adequacy of existing flight-qualified hardware or the developmental status of individual items of equipment that will satisfy the requirement. The engineering documentation for a specific item of equipment will normally proceed to the point where flight-qualified equipment can be identified in the RAS and specifications are available. At this point, the contractor end item (CEI) number will be entered into the documentation, and the specification for that item will then become a part of the documentation.

The longer the end-item lead time to flight qualification, the more complex the documentation will be. This increasing complexity is in the following general order: (1) ground-based laboratory equipment that must be flight-qualified, (2) ground-based laboratory equipment that must be modified and then flight-qualified, and (3) new equipment requiring development, testing, and qualification.

For undeveloped items of equipment, additional documentation normally prepared will include equipment block diagrams, schematic block diagrams (1st, 2nd, and 3rd levels), design sheets, and design sheets assembled into a procurement specification for equipment modules. As additional information is developed on an end item of equipment, the RAS will be revised to include detailed equipment specifications.

Section 3
MODULE AND CREW REQUIREMENTS

AAP guidelines indicate that experiment equipment will be stowed at launch in experimental canisters in the MDA and later translated into the OWS for experiment operation. The Phase B, Section I effort resulted in the recommendation that the IMBLMS Physiological/Behavioral/Data Management (PBDM) and Biochemical stations be designed as an integrated part of an experimental canister (Fig. 3-1). The difficulty in translating large masses through AAP cluster hatches – as demonstrated in recent NASA/USAF, zero-g, parabolic translation experiments – and the need for providing a more centralized and flexible station designed for optimal astronaut performance in the zero-g environment have resulted in the evolution of the cockpit, or wrap-around, station layout (Figs. 3-2 through 3-5). The layout of the crew station permits the tethered astronaut to maintain his operating attitude in a relaxed, zero-g position without any physical exertion. All displays and controls are well within the desired visual cones and reach envelopes of the operator. The experimenter can view the subject and measurement-related module displays and controls simultaneously. If the station is placed in the center of the OWS experiment area, he can see the subject over the top of the experiment station.

3.1 MODULE REQUIREMENTS

To ensure the practicality of assigning measurement functions to modules, specified module sizing was based on such factors as equipment and component envelopes, rack mounting, transportability, and standard racking dimensions. Basic module sizes were established as follows: (1) major module, 19 by 19 by 18 in., (2) standard module, 9.5 by 9.5 by 18 in., and (3) submodule, 4.75 by 9.5 by 18 in. A few modules which adhere to the standard multiple of 19 in. are somewhat specialized due to unique equipment configurations (Fig. 3-6); for example, the biochemical centrifuge requires a module envelope of 19 by 19 by 4.75 in. because of the centrifuge arm radius.

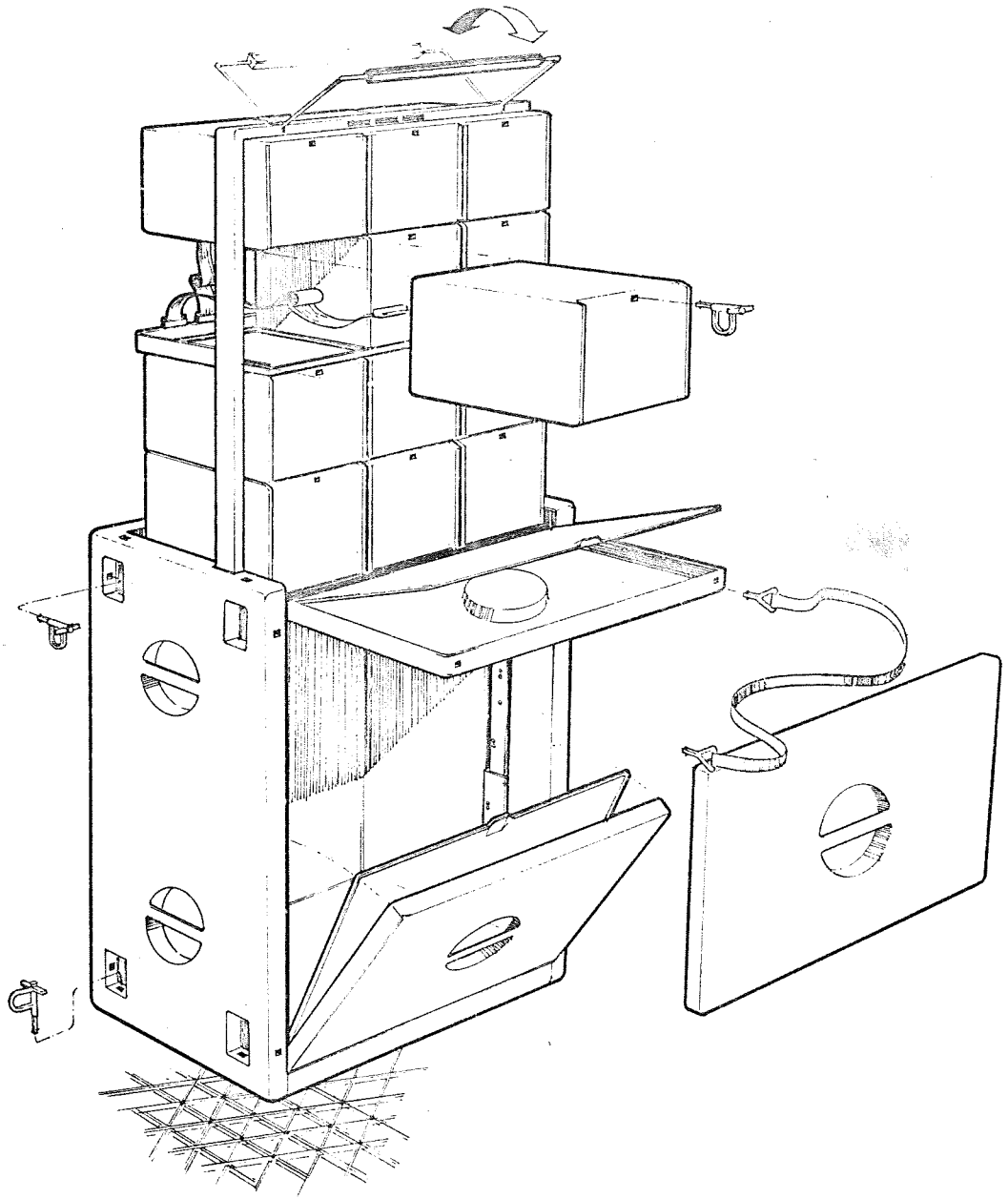


Fig. 3-1 IMBLMS Initial Modulator Elevator Concept – Station Layout

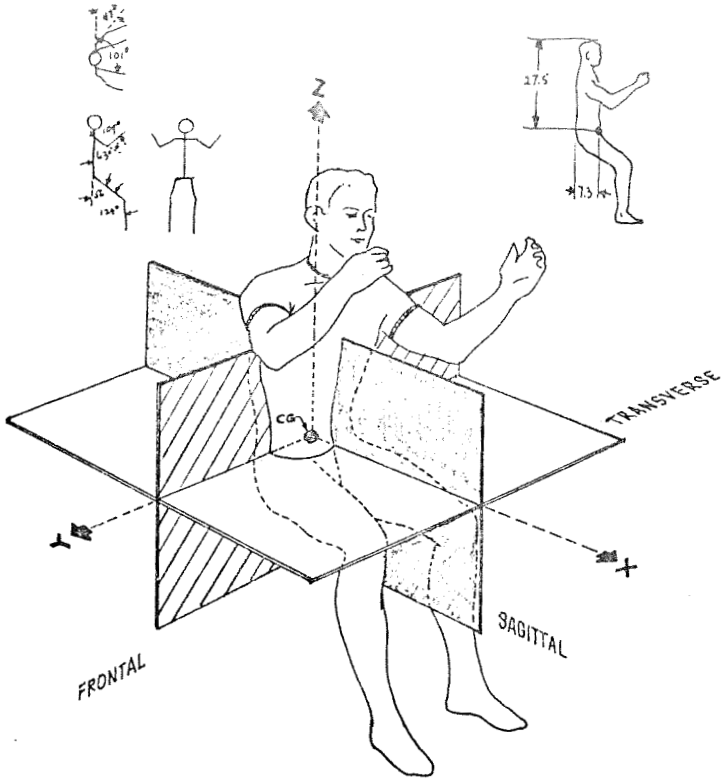
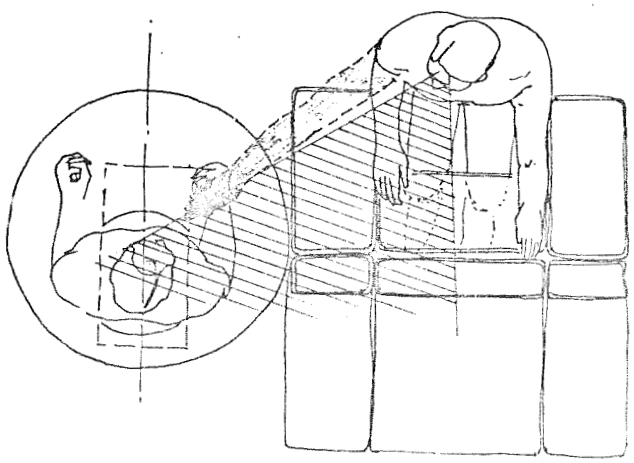


Fig. 3-2 Zero-G Body Coordinate System

Fig. 3-4 IMBLMS Experiment Station – Optimum Experiment/Subject/ Module Relationship



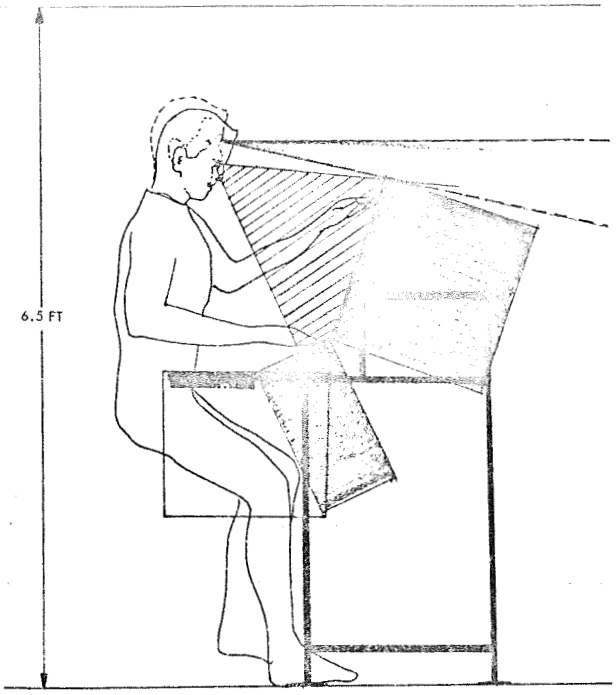


Fig. 3-3 Astronaut in Relaxed Zero-G Position at Candidate IMBLMS Experiment Station – Module Arrangement for Optimum Visual Cone and Astronaut Reach

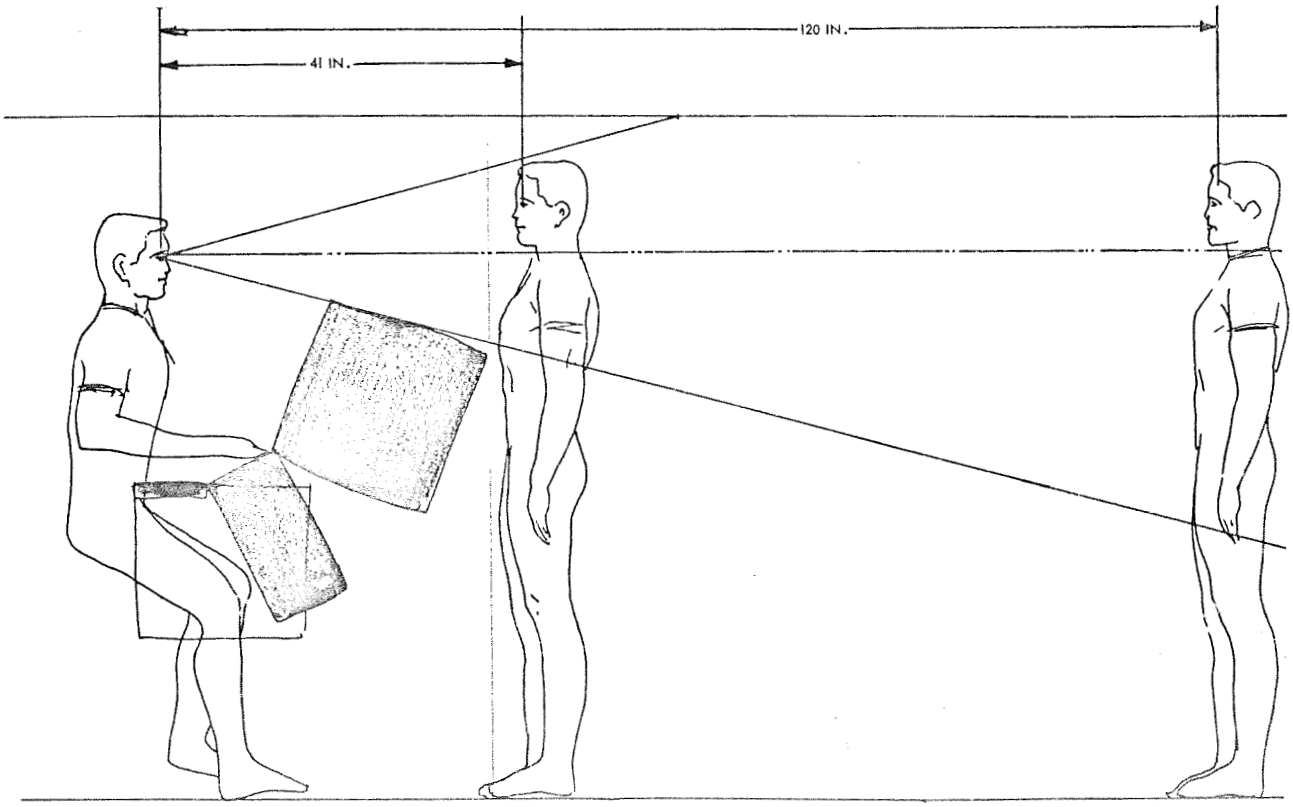


Fig. 3-5 IMBLMS Experiment Station – See-Over Arrangement to Facilitate Subject Observation

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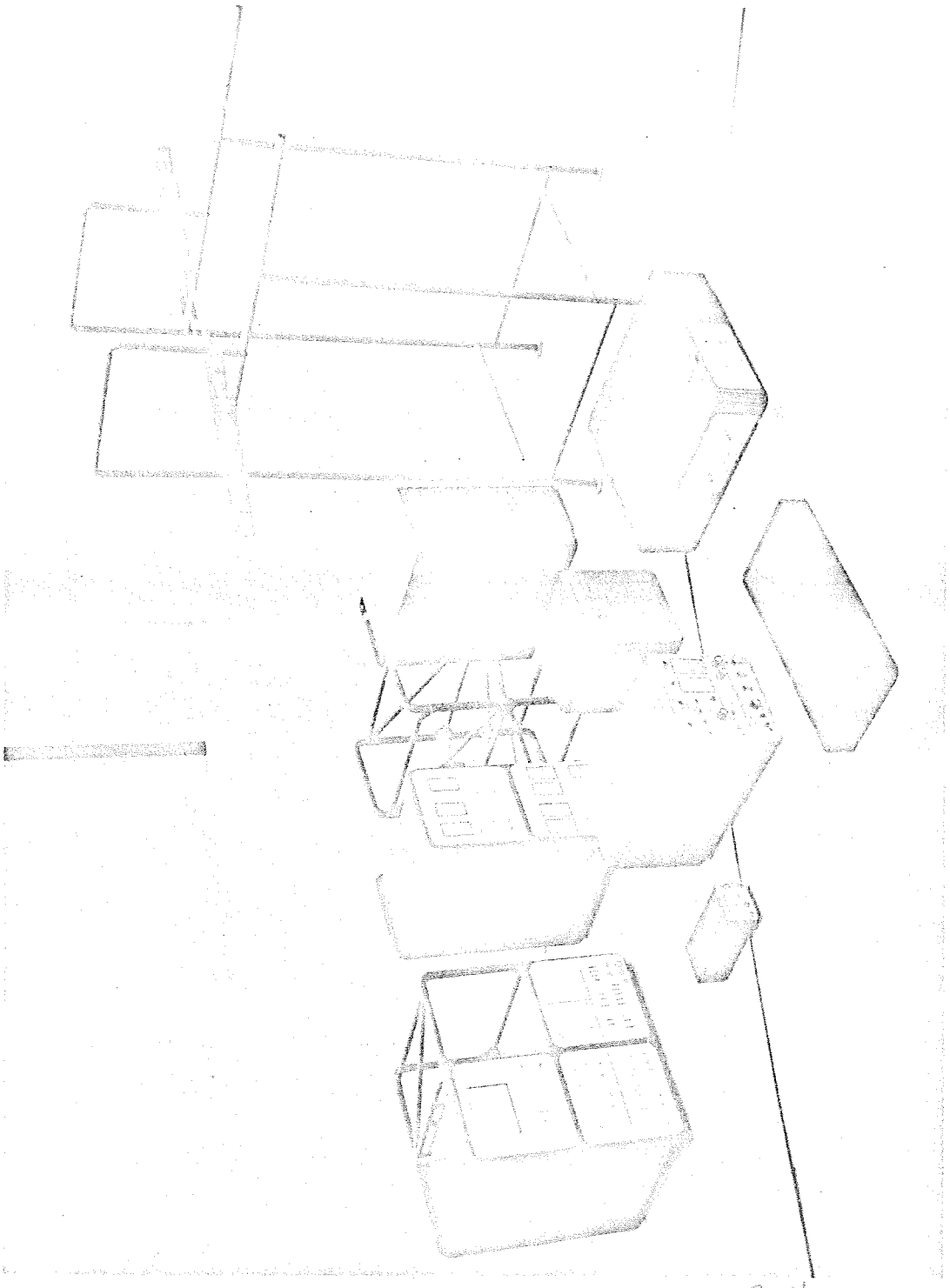


Fig. 3-6 Comparison of IMBLMS Module Configurations

Measurement equipment was grouped into modules and submodules for each of the major body organ systems. This type of allocation permits maximum measurement flexibility since only required measurement modules and submodules need be flown to meet mission objectives. In the physiology element, for example, blood-gas measurement functions are separated from the standard respiratory measurement functions; and, in the biochemical element, the colorimeter and hematocrit measurement functions have been separated from the electrophoresis and the ion electrode equipment. This subgrouping and arrangement of organ system equipment facilitates the integration of a clinical monitoring station (Fig. 3-7). This station provides the minimum number of modules and stowage capability required for safety monitoring during extended flights.

The data management element (Fig. 3-8) was designed in modules and submodules to facilitate a building-block approach – from a simplified, minimal medium (biomedical tape recorder) to the more sophisticated capability required for a comprehensive IMBLMS. The video recorder, timer unit, printer, memo-recorder, and manual data entry unit are submodularized.

The design of the Biochemical crew experiment station permits its setup in the OWS waste management compartment. This feature ensures that, in the event of liquid spillage, the filtered waste management compartment will contain the liquid and process it through the filter and duct system. Figure 3-9 shows the Biochemical station in a mockup of the OWS waste management compartment. The station has been designed to minimize its volume requirement, thereby permitting its installation in this area. Further, since so many of the determinations require the use of stowed items, the supplies and small equipment are located in a storage module and positioned optimally to the right and at an angle providing easier access to and handling of these items by the astronaut.

The PBDM station is shown in Fig. 3-10. The design layout of the IMBLMS stations facilitates modular interchange, as well as add-on growth. The modules can also be mounted very easily in a lightweight tubular rack in a dry OWS, and still provide the modular flexibility with almost no penalty to the system compared with a fixed station concept.

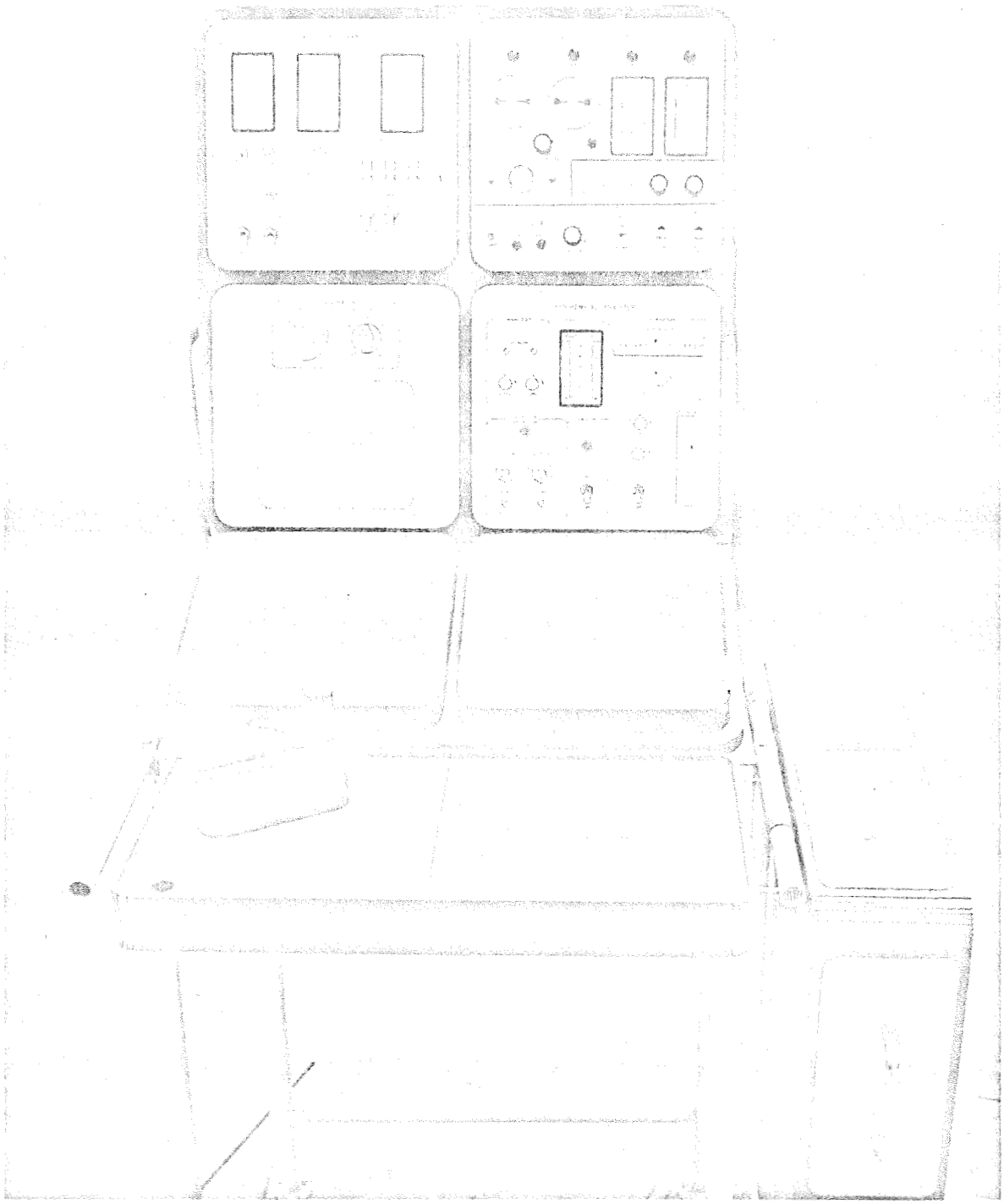


Fig. 3-7 IMBLMS Clinical Monitoring Station – Basic Configuration

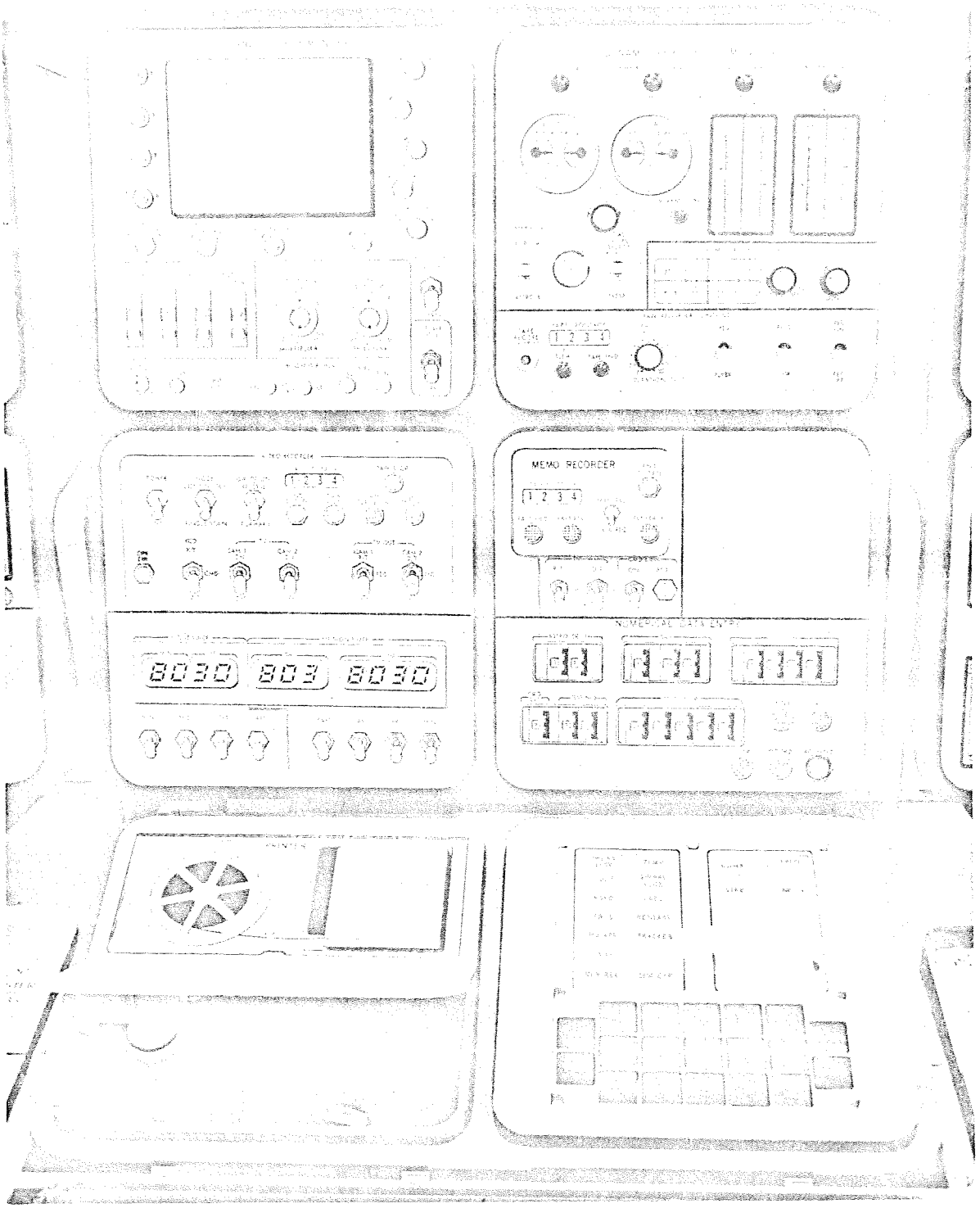


Fig. 3-8 IMBLMS Data Management Element – Modular Configuration

Fig. 3-9 IMBLMS Biochemical Experiment Station in OWS Waste Management Compartment

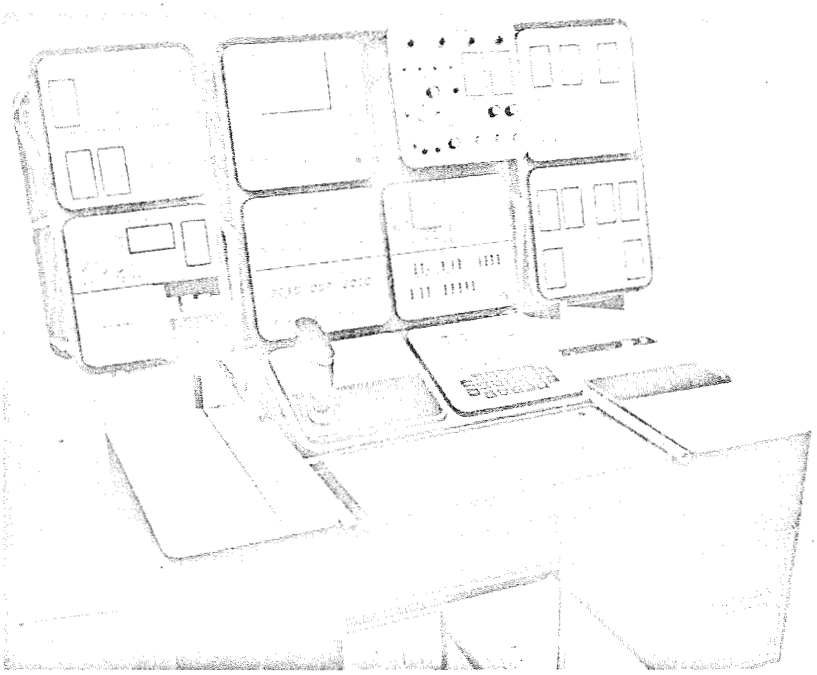


Fig. 3-10 IMBLMS PBDM Experiment Station in OWS Crew Compartment Experiment Area

A workshelf is provided, within which marking instruments, procedures, and logs can be stored. Each station is designed to fit the 10th to 90th percentile of the astronaut user population in a zero-g mode. Simple, quick-disconnect connectors are employed. Sensor/vest/instrument storage (PBDM station) is located in an area which facilitates ease of attachment to the subject and which positions cables, hoses, and umbilicals out of the way. Modules are designed for rack interface so as to be easily removable and replaceable from the front once they are disconnected. Rack structure is provided for addition and growth of modules. The module skins protect the internally mounted equipment and components, thus eliminating the need for canister housings for MDA installation.

3.2 MODULE PANEL CONFIGURATION

Full-scale mockups of each module and submodule were fabricated on the basis of study of the measurement function allocation. These mockups were used to evaluate the internal envelope adequacy and to develop detailed, full-scale panel layouts. The module and submodule mockups and the panel layouts were assembled onto the crew experiment station racks (Figs. 3-11 and 3-12) to verify: (1) location of displays and controls within the visual cone and reach actuation envelopes of the astronaut, (2) arrangement of displays and controls in proper relationship to related module counterparts, and (3) positioning of displays and controls positioned on the panels for maximum ease of operation.

3.3 TRANSFER OF IMBLMS FROM THE MDA AND SETUP IN THE OWS

At liftoff, the IMBLMS experiment equipment is installed in the MDA, in which it remains on orbit until the OWS is made habitable, and the equipment can be transferred to and setup in the OWS crew experiment compartment. The PBDM and Biochemical stations are mounted in the MDA in such a manner that, if the OWS should be uninhabitable, both stations could be operated.

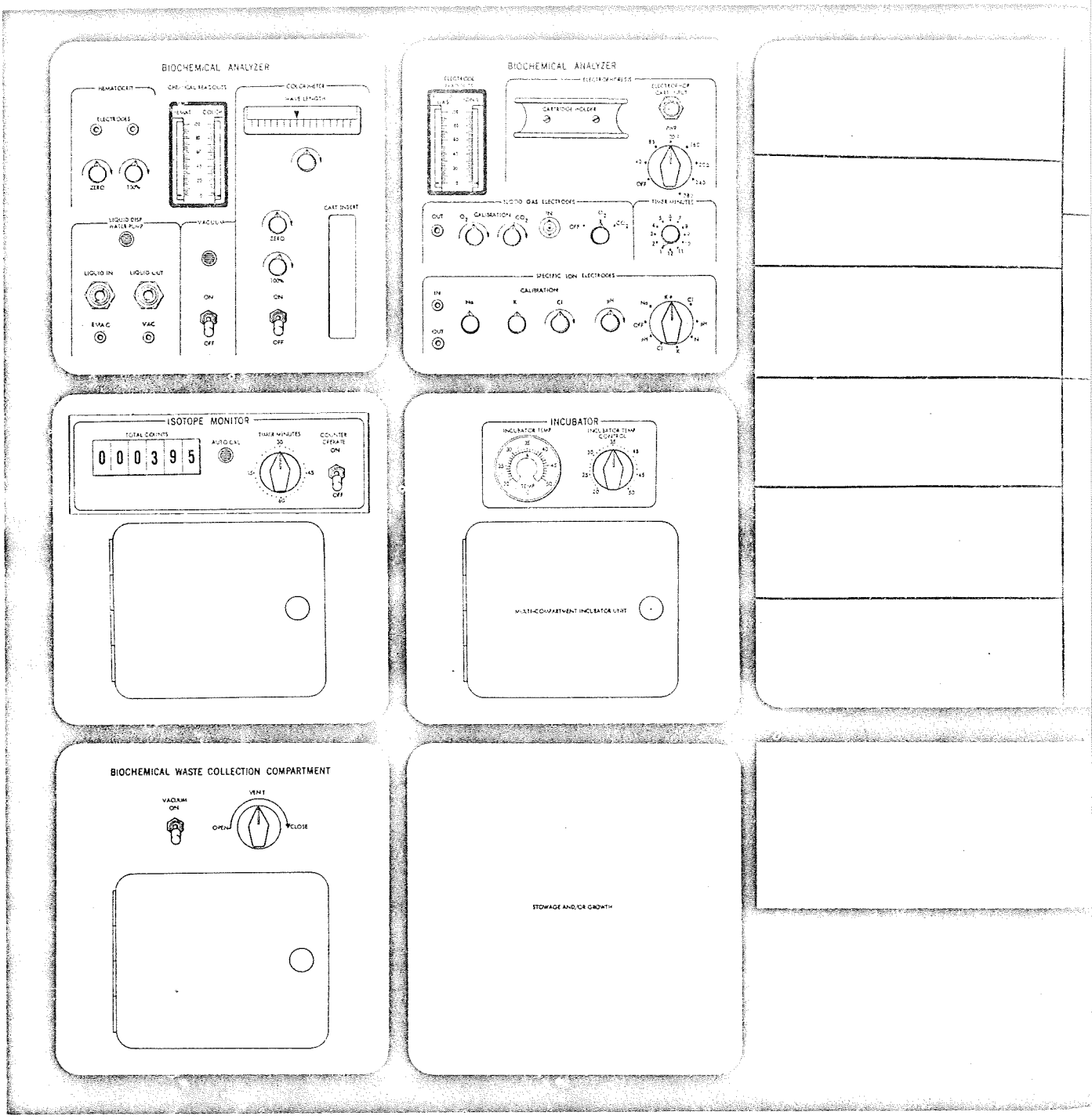
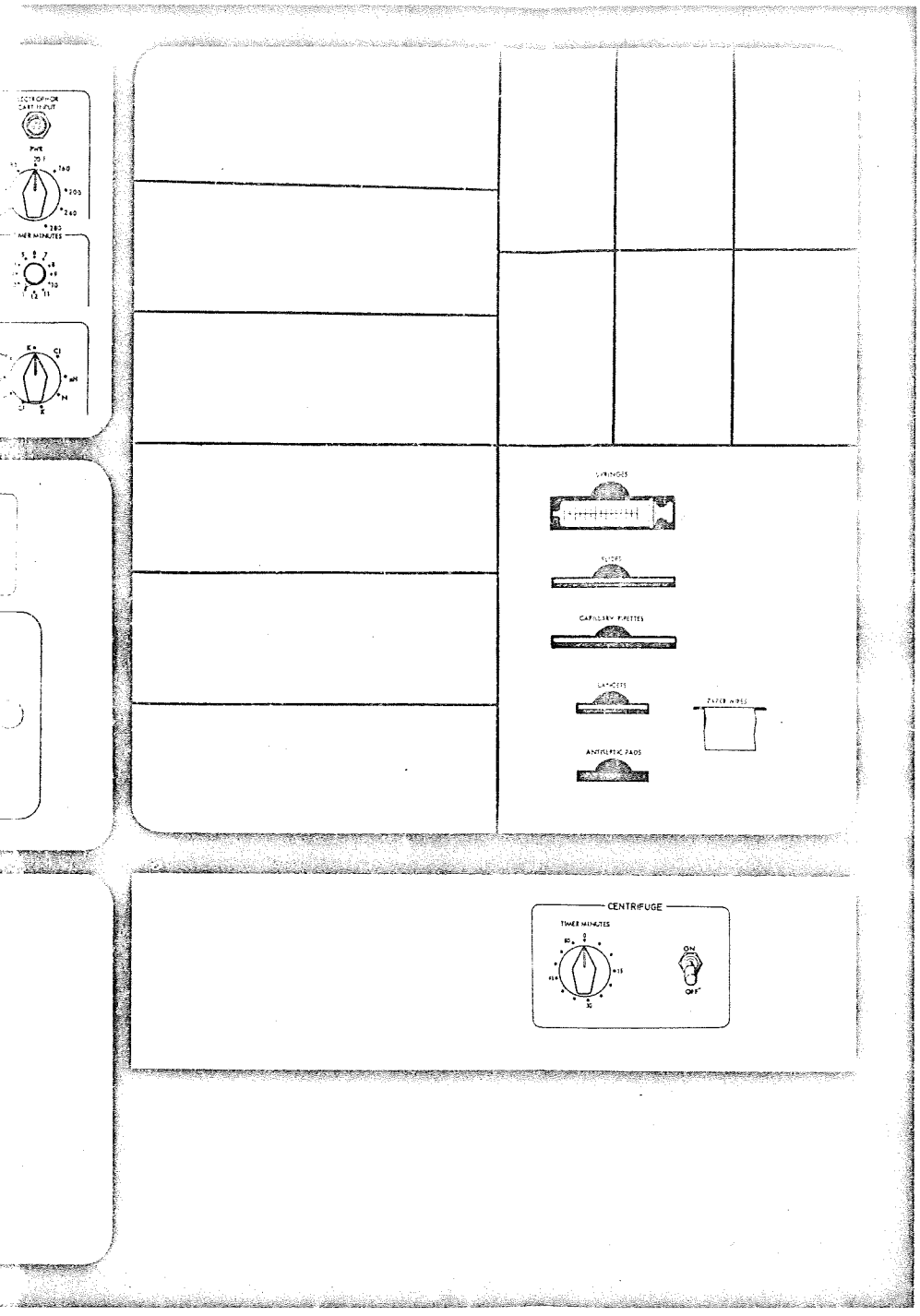
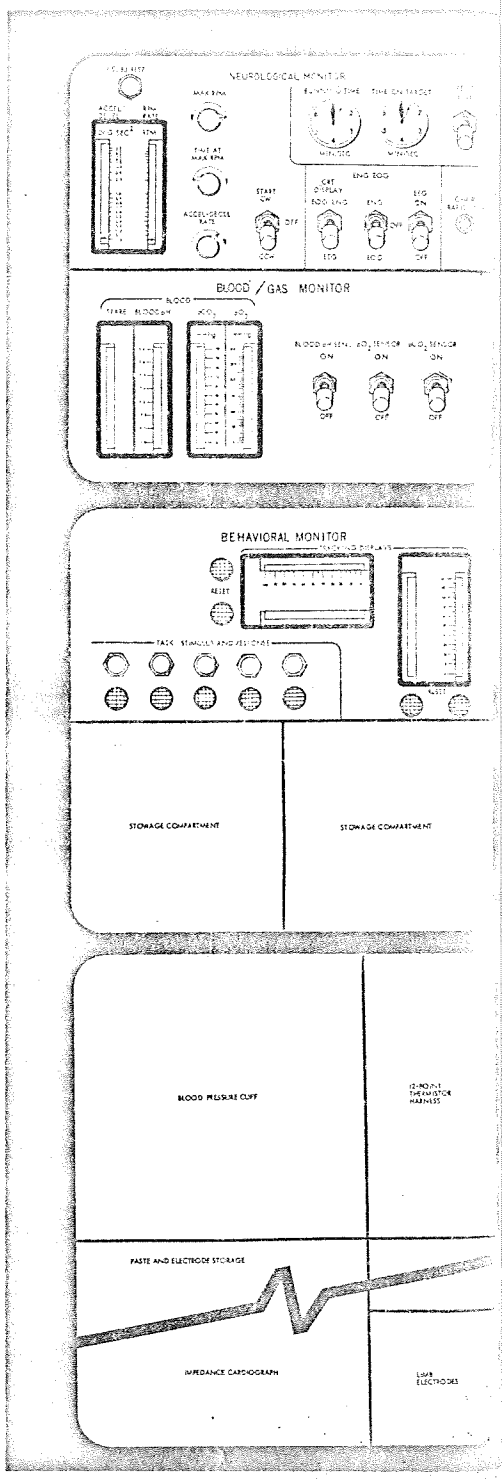


Fig. 3-11 IMBLMS Biochemical Module Panel Layouts





nical Module Panel Layouts

3-11a

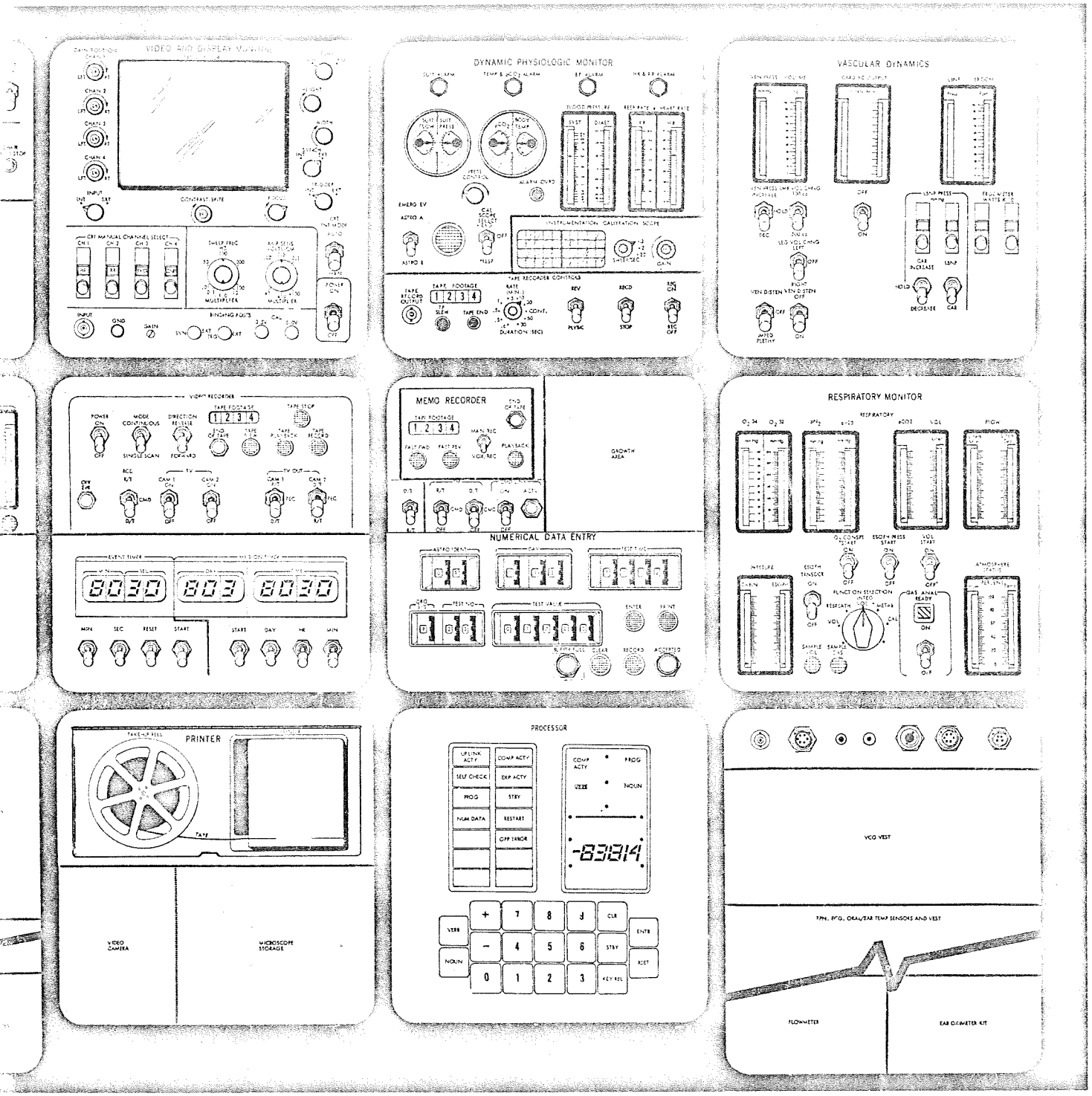


Fig. 3-12 IMBLMS PBDM Module Panel Layouts

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Other major peripheral equipment items that are larger than the major modules are installed on special racks or in canisters within the MDA. Each of these larger items is transported individually from the MDA to the OWS and mounted in its appropriate location in the crew compartment. The simple, tubular-frame racks for both of the experiment stations are pre-installed to reduce astronaut setup time and effort. Two alternate concepts are recommended to accomplish equipment transfer through the Airlock Module (AM) and down the "fireman's" pole into the OWS crew compartment experiment area. The first is a one- or two-man transport mode using pistol grip "stud guns" which attach themselves directly to the experiment package. In addition, a strap and handhold on the rear of the package (shield approach) can be used. The other concept is an LMSC-developed technique, involving a dumbbell-bar approach; two packages are connected by a tube with a pistol grip. This method permits the equipment to be held as close as possible to the center of gravity, and provides visibility when translating the two packages.

The data management module group is removed from the MDA mounting rack and transferred to the pre-installed mounting rack in the OWS. It is then secured to the base, and the astronaut returns to the MDA. The remaining four modules of the PBDM are removed from the MDA mounting rack, assembled into the transport configuration, transferred to the OWS, and remounted on the station rack adjacent to the data management modules. Power, data management, and communication lines (pre-installed or set up in the OWS by the astronauts) are connected to the appropriate modules of the experiment station. The cables and lines of the IMBLMS modules are next interconnected, and the front protector panels are removed from the modules. The work surface area is folded down, completing the setup operation.

The Biochemical station setup is identical to that just described except that the modules are installed in the waste management compartment of the OWS. The Biochemical modules are also mounted on a pre-installed experiment station rack. The connectors are mated to the waste management area interfaces (vacuum, urine and fecal collector etc.); the cables and lines of the modules are interconnected; the front protector panels are removed; and the workshelf is unfolded into operating position.

3-12

3-12

The dynamic physiologic monitor, and possibly two to three Biochemical modules, may be used in locations other than in the MDA or OWS. In the case of the dynamic physiologic monitor, simple mounting brackets will be provided in the AM (to permit evaluation and safety monitoring of the EVA astronaut) and in the Command Module (CM) for safety monitoring. The Biochemical modules may be used on the synchronous-orbit flights, and could be located in the Refurbished Command Module (RCM). These modules are generally 9.5 by 9.5 by 18 in. or less, thus ensuring that they can be easily transported through any of the spacecraft hatches.

3.4 IVA AND EVA EFFECTS ON IMBLMS

There will be minimal EVA effects on the IMBLMS, since the crew will not be performing specific IMBLMS experiments while outside.

Two crew members will be associated with the EVA (one in the airlock and one outside the vehicle) while the other astronaut is in the CM monitoring the cluster system. Some biomedical safety measurement will be performed during EVA, and the dynamic physiologic monitor will be transported to the airlock (thus possibly involving vacuum use) for the internally stationed astronaut to use in monitoring the crewman performing EV tasks. Still under consideration is the question of whether near-field telemetry or umbilical signal routing will be employed, and the decision could affect IMBLMS design. In all likelihood, all tasks associated with rendezvous and spacecraft docking will be conducted with the crew in the CM, for reasons of safety.

In total, there appears to be little EVA effect on the total IMBLMS, particularly during the early Cluster A and B flights.

Intravehicular activity could affect the IMBLMS, particularly those measurements associated with respiratory functions in which the environment of the OWS experiment area will have to be monitored closely and cannot be changed significantly during the measurement task. Experiment setup and conduct of non-IMBLMS measurements

could also affect the IMBLMS, depending on the nature of the task, e.g., Lunar Module/Apollo Telescope Mount (LM/ATM) spacecraft stabilization and orientation. During LM/ATM solar measurements, complete crew quiescence must be maintained to assure telescope pointing accuracy. When individual astronauts are conducting experiment activities in two separate fields (e.g., IMBLMS and astrophysics), competition may arise for power, data management processing, communication, etc. Furthermore, the necessity to perform a non-IMBLMS measurement, in any area other than where the IMBLMS may be set up, reduces the availability of subject personnel. If remote monitoring of an astronaut in the Cluster is desired (e.g., in the CM), it will be necessary to transport an IMBLMS module to the site and set it up. Also, the scheduled use of the food and waste management compartments will influence IMBLMS activities. Work/rest/sleep cycles are important to the measurement frequency and subject availability, as are the operational and housekeeping duty cycles.

3.5 PRELIMINARY OPERATIONAL ANALYSES

There will be no crew interface with IMBLMS experiment equipment on the pad prior to liftoff, nor any involvement during the launch and orbit-attainment phases. In orbit, standard orbital setup operations will precede any scientific or engineering experiment programs, as will rendezvous and docking of spacecraft with the Cluster. It is anticipated that 2 to 3 days may be required to set up the Cluster in an operational mode after which the crew can initiate experiment programs.

If a LM/ATM vehicle is involved, considerable time will be required initially to set up and stabilize the spacecraft. Should the mission phase under consideration be a typical resupply/crew-rotation flight, there will be only a minor delay (1 day or less expected) in reactivation or continuance of the experiment program. It is anticipated that every seventh day will be allocated to minimum astronaut participation to permit rest, relaxation, and change of routine. Previous LMSC Biolabs time-line studies (Ref. 3-1) indicate that approximately 38 percent of the total available experiment time in a 45-day flight will be required to conduct a "complete" NASA-defined

biomedical/behavioral measurement program. There appears to be no requirement for real-time data management dump to the ground, so that station contact schedule compositions are reduced. Toward the end of the mission, flight samples and data to be returned to the ground will be transferred from the experiment areas to the CM and stowed. The crew will then initiate pre-reentry procedures, and the countdown will be started. From this point to recovery, the crew will not be involved in the measurement program or with samples or data acquired on orbit. After splashdown or touchdown, the recovery team probably will be responsible for the removal of samples and data from the CM for ultimate transportation to the appropriate receiving facility.

Section 4
MISSION AND SPACECRAFT ANALYSIS

The Cluster A and B missions and five associated spacecraft are analyzed in this section as they relate to the IMBLMS experiment and measurement program. The five spacecraft are the Refurbished Command and Service Module (RCM); Lunar Module Laboratory (LM-Lab); Multiple Docking Adapter (MDA); S-IVB Orbital Workshop (OWS), wet concept; and S-IVB Orbital Workshop (OWS), dry (or ground-fitted) concept.

4.1 CLUSTER A AND B MISSION ANALYSIS

The IMBLMS currently is identified with the AAP Cluster B flights in 1971 and beyond, although selected portions of the system could be available for earlier flights if it is developed on an accelerated schedule. The Cluster concept is basically the on-orbit rendezvous and docking of several spacecraft with an S-IVB spent stage; this stage incorporates an Airlock Module (AM) and MDA which are integrally fitted into the S-IVB Saturn LM Adapter (SLA) at lift-off. These spacecraft (CSM, LM, RCM, etc.) are launched and rendezvous with and dock to the MDA, resulting in a clustered configuration of a variety of orbiting spacecraft. The S-IVB spent stage is made habitable, and the entire cluster assembly is employed as an operations and experiment orbital station.

4.1.1 Cluster A Mission

The Cluster A mission is composed of five flights employing an S-IVB spent stage (OWS), MDA, AM, Lunar Module/Apollo Telescope Mount (LM/ATM), and manned RCM. These flights are planned for the period from 1969 to 1970. The crew size is three, and the circular orbital altitude is planned at approximately 210 nm. Flights AAP-1 and 2 are scheduled for up to 28 days. Current plans call for an RCM visit to

the Cluster during a 56-day mission, with the emphasis on biomedical experimentation. Flights AAP-3 and 4 are scheduled for up to 56 days, with major emphasis on solar astronomy and biomedical experiments. A mission profile for Flights AAP-1, 2, 3, and 4 is presented in Fig. 4-1. Flights AAP-5, 6, and 7 will revisit the cluster for periods up to 56 days.

4.1.2 Cluster B Mission

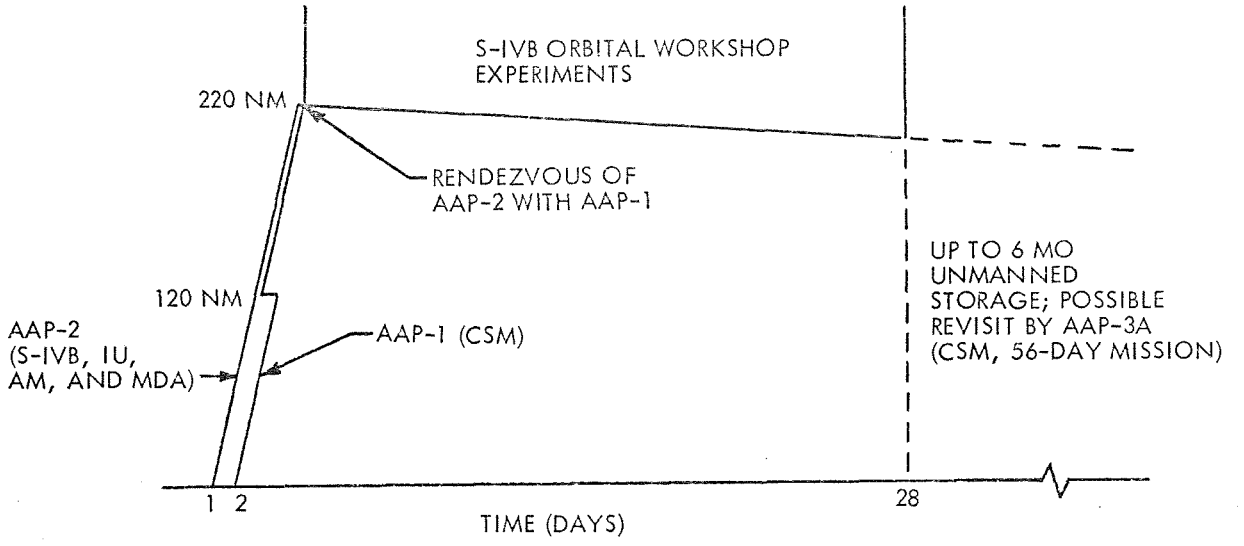
The Cluster B mission is in the early planning stage and, therefore, only meager details are available. Initially, it was conceived that this program would be a 10-flight mission beginning in 1970 and continuing until late 1971. The cluster would employ an S-IVB OWS, MDA, AM, and LM, and a Logistics Command and Service Module for resupply. The cluster would be placed in a circular, 260-nm orbit; tentative plans were to use the OWS for 2 years. Resupply flights would occur every 90 days, with potential for crew rotation; crew size has been estimated at from three to as many as nine men.

The Cluster B mission will provide the first real opportunity for a comprehensive space biomedical evaluation, considered a primary mission objective in view of the goal of space missions of 1 to 2 years.

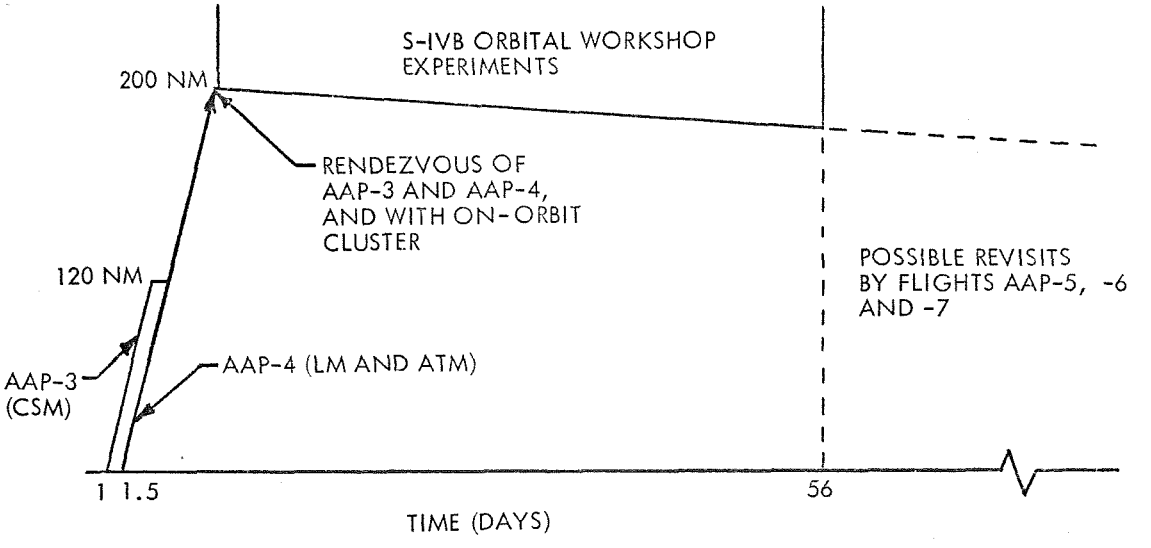
Although mission plans and spacecraft selections are indefinite, it can be assumed for IMBLMS planning purposes that either similar vehicles identified for Cluster A or vehicles of greater capability, such as a dry-launched S-IVB, will be available.

4.2 AAP CLUSTER SPACECRAFT

Five spacecraft associated with the cluster concept have been investigated as IMBLMS carriers: RCM, LM Lab, MDA, wet OWS, and a dry (ground-fitted) OWS. OWS offers the most advantageous vehicle for performing IMBLMS experiments on orbit (see Section 6.10). The dry-launched OWS provides the greatest reliability, since IMBLMS equipment could be installed on the ground in the operating configuration, and checked



(a) FLIGHTS AAP-1 AND AAP-2



(b) FLIGHTS AAP-3 AND AAP-4

Fig. 4-1 AAP Mission Profiles

out and made ready for utilization almost immediately after attainment of orbit. The other spacecraft, in order of preferred use for IMBLMS, are the MDA, RCM, and LM Lab. The MDA provides adequate volume for the conduct of IMBLMS experiments (with the possible exception of the REVS experiment). Deployment of IMBLMS in the RCM would allow only minimal room for two astronauts and no other experimental equipment. The LM has inadequate free-swept volume to conduct IMBLMS experiments with large items of peripheral equipment (e.g., LBNP).

4.2.1 Lunar Module Laboratory (LM Lab)

At present, there appear to be no specific plans to refurbish an LM to develop a "gutted" LM Lab. Current AAP mission planning calls for the utilization of an LM, with minimum modifications for support of the ATM experiments. The LM would house the display and control station used in consort with the ATM experiments. The ATM would be mounted beneath the LM, in place of the descent stage, in a rack structure. Thus, the LM/ATM is used principally in support of solar experiments for observing, monitoring, and recording solar phenomena.

In the event a gutted LM were to be developed for an AAP experiment laboratory, several modifications would be required – such as removal of Lunar-oriented guidance and navigation equipment, removal of the ascent-descent stage, positioning of a plate over the ascent engine cover, etc. These modifications probably could not be made at Cape Canaveral and would necessitate factory implementation. There are two principal experiment areas in a gutted LM Laboratory which might be considered for IMBLMS experimentation. The first is the main cabin area, which contains the main lunar descent display-control panel and includes the viewing ports and egress-ingress forward tunnel and hatch; the main cabin is approximately 90 in. wide by 35 in. deep by 80 in. high (146 ft^3). The other area is the midsection (adjacent to the main cabin), in which the crew-transfer/docking tunnel and engine cover are presently incorporated; the midsection is approximately 58 in. wide by 54 in. deep by 60 in. high (96 ft^3). The midsection and main cabin walls are not flat so that equipment installation presents a problem,

and considerable orbit-required electrical and environmental equipment is mounted on the walls. The docking tunnel hatch is approximately 30 in. in diameter, which somewhat reduces the size of experiment packages which can be transported into the laboratory.

The larger items of IMBLMS experiment equipment – e.g., rotary chair, mass measurement device, LBNP, ergometer, etc. – require too much volume to stow in the LM Lab. Furthermore, it is highly questionable if there is sufficient free-swept volume available for their use. Transfer of these items from the MDA into the laboratory might prove difficult because of the smaller hatch size. It is also doubtful that the IMBLMS experiment crew stations, peripherial equipment, large experiment equipment items, and two men could function adequately in the LM Lab.

4.2.2 Refurbished Command and Services Module (RCM)

The RCM is derived from the Apollo Block II CM through the refurbishment of a previously flown vehicle. With the removal of the crew couches, approximately 40 ft^2 of "standup" area is available, and nearly 360 ft^3 of free volume is exposed by removal of non-essential equipment. Sufficient free volume exists for experimentation employing the use of measurement equipment which requires large free-swept volumes. These items could be transported to the RCM from the MDA for experiment use; however, if they were left within the RCM, very little extra volume would exist for other engineering or scientific experiments using equipment requiring large freeswept volumes. LMSC has constructed an RCM mockup for evaluation of experiment station layout and has identified three major areas of potential equipment installation against the bulkheads of the internal cabin. These areas are as follows:

- Directly beneath and to the left of the midline of the tunnel – 28 in. wide by 16 in. high by 9 in. deep (2.5 ft^3)
- Directly beneath and to the right of the tunnel edge – small item storage
- Directly beneath the window – 40 in. wide by 32 in. high by 16 in. deep (12 ft^3)

- To the right of and above location where backpack is stowed temporarily - 32 in. wide by 32 in. high by 16 in. deep (9.5 ft^3)

If the IMBLMS were deployed for operation in the RCM, there would be only minimal room for two persons. There is no filtered compartment; hence, biochemical analyses involving liquids would have to be designed with special care. It appears possible to stow all of the IMBLMS within the RCM; however, little space would be available for any other engineering or scientific measurement equipment.

4.2.3 Multiple Docking Adapter (MDA)

The MDA is a cylindrical pressure vessel approximately 17 ft long. It is cantilevered from the AM structural transition section (STS) at one end and tapers to an axial docking port at the other end. Four additional docking ports are spaced at 90-deg intervals, radial to the cylindrical section. A grid floor, normal to the longitudinal axis, is located approximately 23 in. below the centerline of the radial docking port. Four flat grid walls, parallel to the longitudinal axis, are mounted between the STS and the grid floor. Experiments and equipment can be mounted on both sides of these walls.

Approximately 800 ft^3 is available in the MDA for equipment storage; with equipment installed, there is approximately 5 to 6 ft^3 of free-swept volume extending down the length of the 13.5-ft, constant-diameter cylinder. The diameter of the hatch to the AM is approximately 40 in., permitting transfer of experiment equipment packages of up to 20 in. by 30 in. by 40 in. Once on orbit, the MDA will be provided with a two-gas atmosphere, and umbilicals will be provided to receive power and data management control from the AM. Astronaut tether and mobility aids will permit experiment operation as well as dismounting and transport of experiment packages.

There is sufficient available volume in the MDA to conduct the IMBLMS experiment program in the event the OWS is not habitable. With the possible exception of the rotary chair, adequate free-swept volume exists for conduct of measurements employing the larger experiment equipment. The crew experiment stations can be set up and

deployed in the MDA with minimum restriction to crew passage. The MDA appears to be the best spacecraft for backup to the OWS for IMBLMS experiments and measurements.

4.2.4 S-IVB Orbital Workshop (OWS), Wet Concept

The OWS is essentially an S-IVB spent stage, purged and readied for astronaut occupancy. The LH_2 tank used for manned activities is approximately 22 ft in diameter and 26 ft long (10,460 ft^3). A flat, open-mesh partition, both sides of which are usable as a floor, is installed approximately 96 in. above the common bulkhead and perpendicular to the tank wall. A ceiling consisting of pre-installed handrails will be located between the floor and the common bulkhead, 78 in. from the floor (Fig. 4-2). A cloth ceiling, between the handrails and the common bulkhead, will be installed on orbit. Pre-installed walls will partition the volume between the floor and ceiling into five compartments – two for sleeping and, one each for food management, waste management, and experiments (the latter 1,300 ft^3). The food and waste management compartments are enclosed to prevent odor and liquid contamination of other areas, and each is provided with a venting-fan system. A port with a diameter of approximately 3 in. is provided through the insulation and skin of the LH_2 tank. A valve is mounted in this port for disposal of biological waste and to provide a vacuum source for experiments. A hardline voice communication link is provided from the OWS via the AM to all modules of the Cluster. Pre-installed wiring distributes electrical power and data management to selected points in the OWS.

Experiment equipment will be mounted in the OWS crew compartment experiment area – either on the grid floor, on grid walls of the crew compartments, or on special mounting rails between the thermal curtain hat sections on the tank wall. Equipment packages will be transported to the OWS from the MDA, through the AM, and down the "fireman's pole" into the crew compartment for subsequent installation, set-up, and operation. There is more than adequate volume in the OWS crew compartment experiment area for the installation and operation of the IMBLMS, including the large peripheral measurement equipment items.

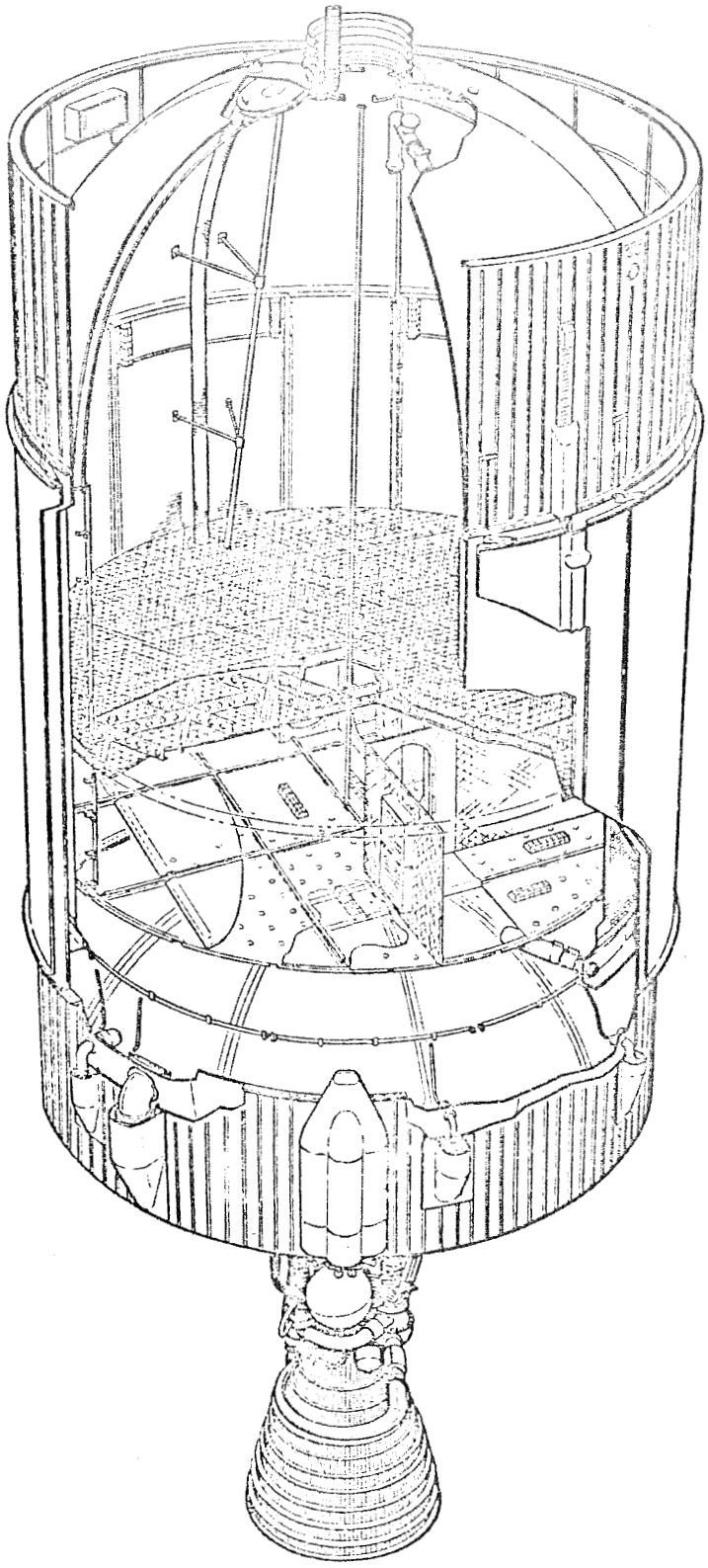


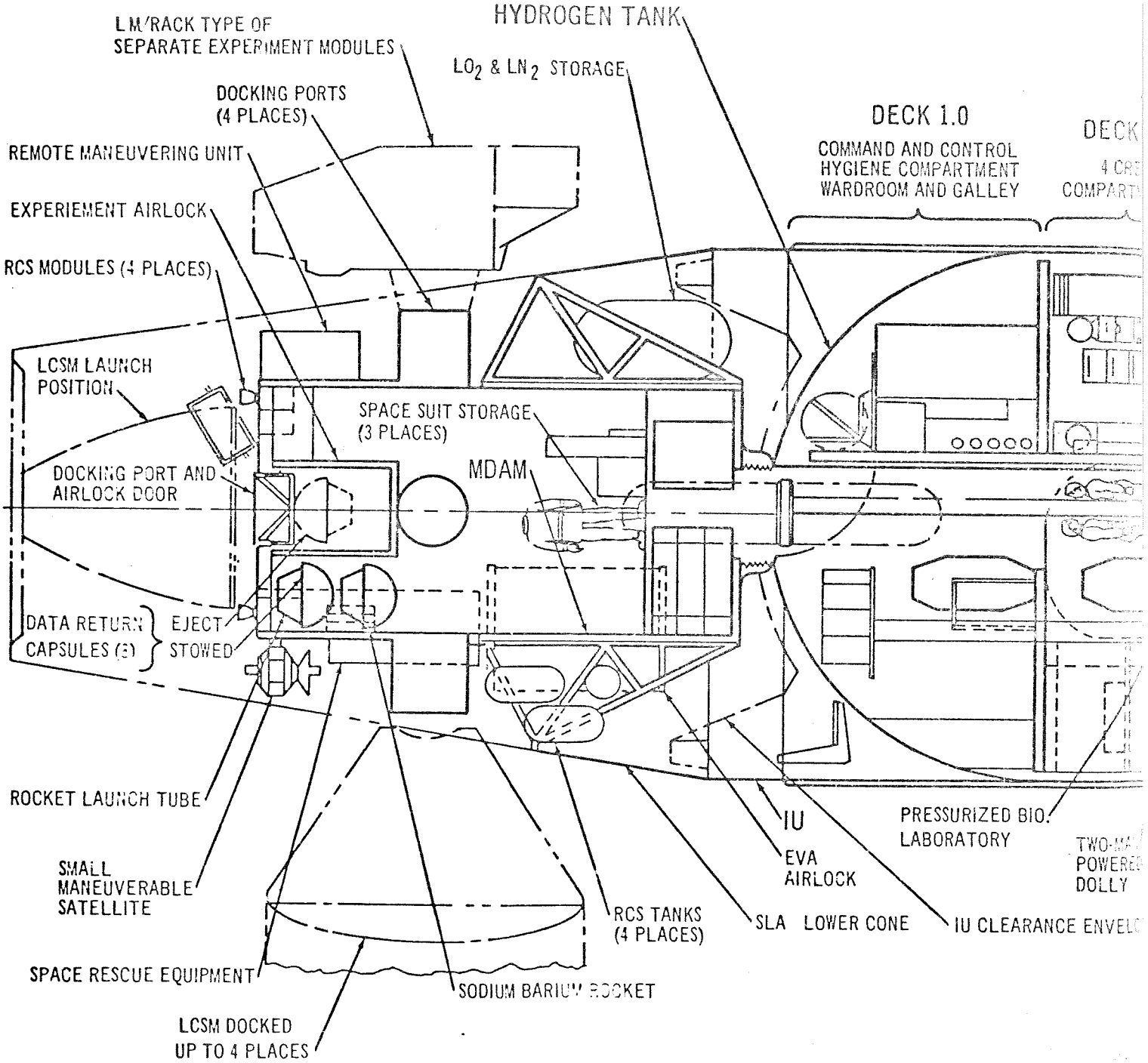
Fig. 4-2 Saturn-IVB Orbital Workshop – Wet Concept

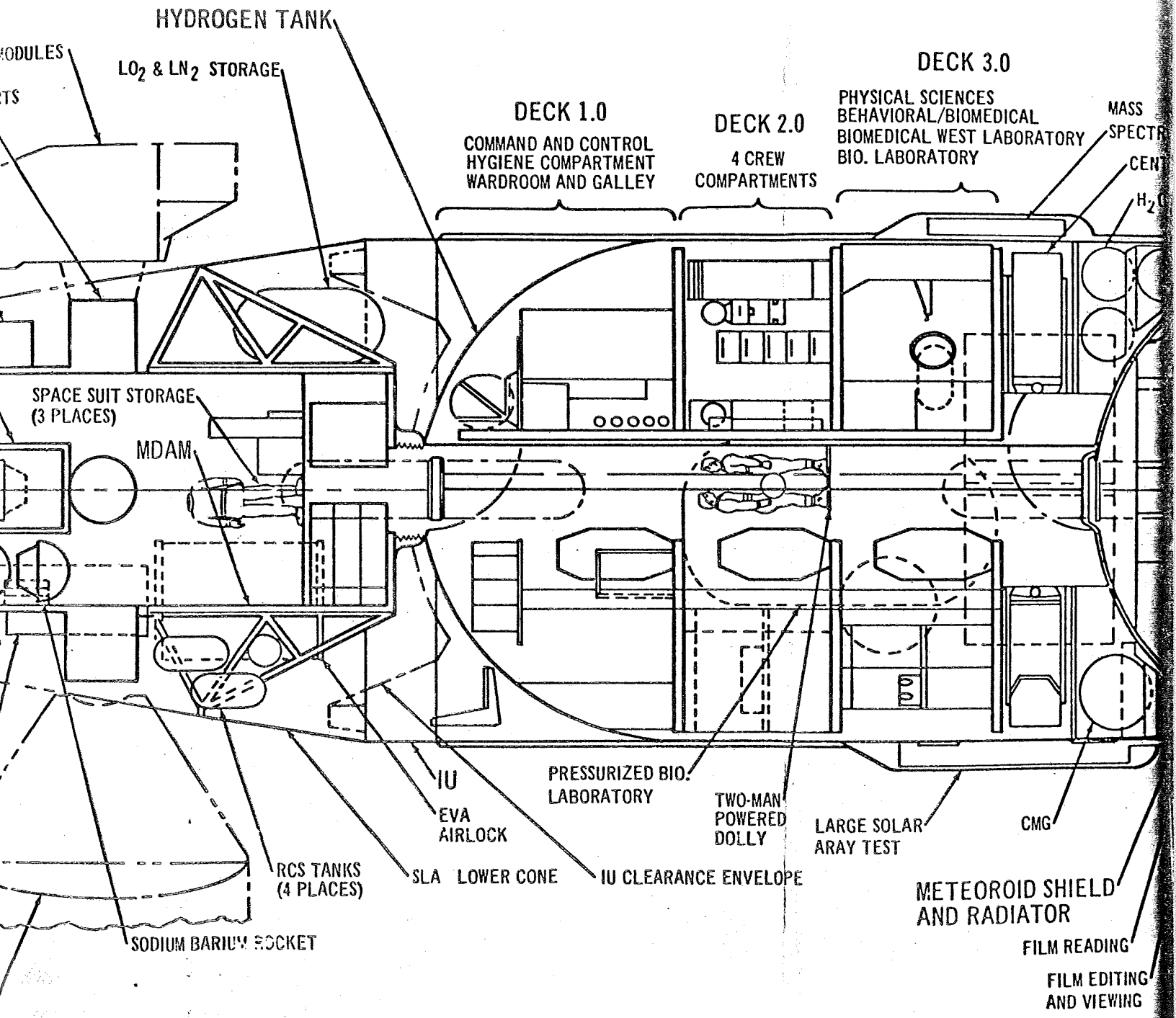
4.2.5 S-IVB Orbital Workshop, Dry (or Ground-Fitted) Concept

The S-IVB OWS, launched in a dry configuration, is essentially an evolutionary application of the S-IVB structural shell – modified and ground-outfitted for use as an orbital laboratory. Station docking facilities are provided with a modified Multiple Docking Adapter Module (MDAM) mounted in the LM attach fittings forward and the single-docking AM on the interstage conical surface aft. The docking adapters accept normal CSM-LM docking fittings. Exterior module operations and EVA are centralized in the forward region of the station module around the MDAM. A secondary dock and EVA port is located in the aft interstage surface. The central region of the station module (S-IVB pressure vessel) contains the crew, control, and internal laboratory facilities that operate in a shirtsleeve environment. In addition to the internal experiment laboratories, the major experiment installation occupies the entire truncated cone of the S-IVB/S-II interstage aft, a volume of 8,500 ft^3. The astronomy module and the Earth-sensor module are environmental volumes with direct crew access from the oxygen tank for maintenance and servicing. Exterior doors on the module provide direct exterior viewing after the atmosphere has been pumped back into the main station for storage. The remaining experiments require only occasional access through crew EVA, and are space-exposed with aft or side viewing by boom extensions from their stowed position. A limited number of experiments are externally mounted, and a few are stowed in the MDAM and launched through an air lock in the forward face of the MDAM.

The internal station module arrangement consists of three major pressure volumes: MDAM, 1,450 ft^3 plus 120 ft^3 in the EVA airlock; S-IVB hydrogen tank, 10,458 ft^3; and S-IVB oxygen tank, 2,827 ft^3. The oxygen tank is an experiment laboratory region; it services the external aft experiment installation and the aft airlock module, with crew pressurized access to the Earth-sensor module; the astronomy module; and the aft airlock module. Three full-deck levels and a centrifuge occupy the hydrogen tank (Fig. 4-3). Two of the three deck compartments are devoted to crew habitation; one consists of the galley and wardroom, while the second is the hygiene compartment (two toilet facilities and space allocation for a crew shower and laundry facilities). The third compartment is the command and control center.

The third deck can, essentially, accommodate the IMBLMS in two compartments. The total 925-ft^3 volume includes a 225-ft^3, filtered compartment for a biochemical wet laboratory.


LM/RACK TYPE OF
SEPARATE EXPERIMENT MODULES
HYDROGEN TANK
LO_2 & LN_2 STORAGE
DOCKING PORTS
(4 PLACES)
DECK 1.0
COMMAND AND CONTROL
HYGIENE COMPARTMENT
WARDROOM AND GALLEY
DECK
REMOTE MANEUVERING UNIT
EXPERIEMENT AIRLOCK
RCS MODULES (4 PLACES)
LCSM LAUNCH
POSITION
SPACE SUIT STORAGE
(3 PLACES)
MDAM
DOCKING PORT AND
AIRLOCK DOOR
DATA RETURN
CAPSULES (3)
EJECT
STOWED
ROCKET LAUNCH TUBE
IU
PRESSURIZED BIO.
LABORATORY
EVA
AIRLOCK
SMALL
MANEUVERABLE
SATELLITE
RCS TANKS
(4 PLACES)
SLA LOWER CONE
SPACE RESCUE EQUIPMENT
SODIUM BARIUM ROCKET
LCSM DOCKED
UP TO 4 PLACES


HYDROGEN TANK
ODULES
TS
LO_2 & LN_2 STORAGE
DECK 1.0
COMMAND AND CONTROL
HYGIENE COMPARTMENT
WARDROOM AND GALLEY
DECK 2.0
4 CREW
COMPARTMENTS
DECK 3.0
PHYSICAL SCIENCES
BEHAVIORAL/BIOMEDICAL
BIOMEDICAL WEST LABORATORY
BIO. LABORATORY
MASS
SPECTR
CEN
H_2
SPACE SUIT STORAGE
(3 PLACES)
MDAM
IU
EVA
AIRLOCK
PRESSURIZED BIO.
LABORATORY
TWO-MAN
POWERED
DOLLY
LARGE SOLAR
ARAY TEST
CMG
RCS TANKS
(4 PLACES)
SLA LOWER CONE
IU CLEARANCE ENVELOPE
METEOROID SHIELD
AND RADIATOR
SODIUM BARIUM ROCKET
FILM READING
FILM EDITING
AND VIEWING

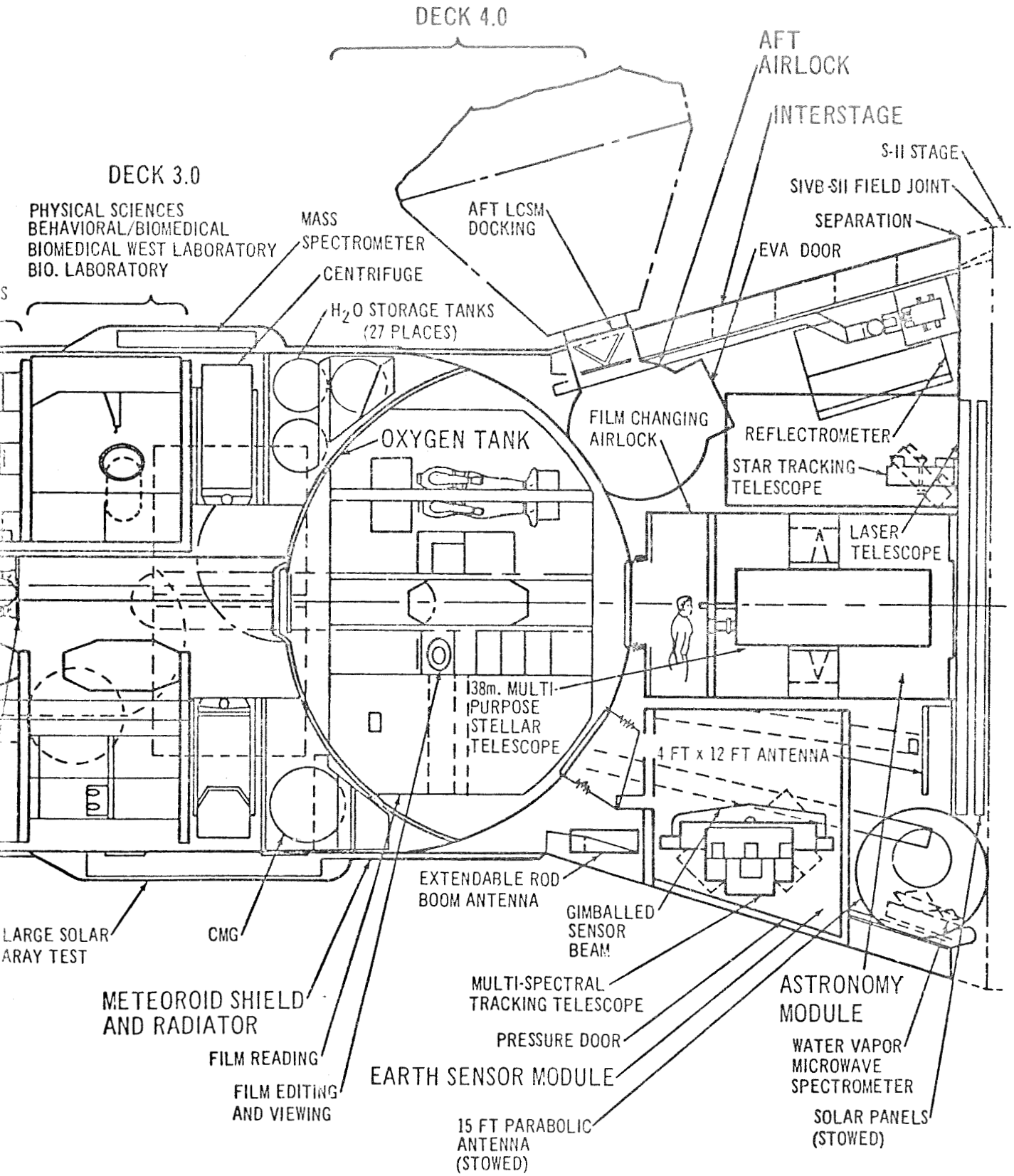


Fig. 4-3 S-IVB Orbital Workshop — Dry Concept

Section 5
DATA MANAGEMENT

5.1 SYSTEM APPROACH

The IMBLMS data management element of IMBLMS was designed to provide the following characteristics and meet related requirements:

- Minimization and simplification of astronaut manual tasks by means of automatic data routing, analysis, and display
- Flexibility for expansion
- Capability for on-board measurement modification
- Instrumentation design parallel to that of AAP

A design which reduces the number of manual tasks to be performed by astronauts promotes astronaut efficiency and system acceptance by the astronaut. Similarly, a design providing simplicity in operation tends to complement these goals. Automatic data routing, analysis, and display are additional steps towards accomplishing this efficiency for astronaut/experimenters and, in the case of an astronaut/physician, constitute a means of providing accurate on-orbit data for his immediate interpretation.

To achieve flexibility for system expansion it was first necessary to design a total data management system. Such an approach permits easy subdivision for the purpose of incremental measurement (as required) support. A capability for on-board measurement modification was provided through the use of high speed random access multiplexing equipment and multipurpose digital displays.

Current AAP instrumentation design concepts are not sufficiently concrete to permit the IMBLMS to become completely dependent on such a system. As a consequence, a paralleling of the current AAP instrumentation design requirements, with close

monitoring of these requirements, will result in an IMBLMS data acquisition system which can be readily adapted to the AAP equipment. A changeover will be possible in either the design stage or during the early hardware stages.

5.1.1 BASIC CONFIGURATION

A review of all the biomedical measurement functional flow diagrams yielded a series of requirements for acquiring, processing, displaying, recording, and forwarding data to the ground. Once the data reaches the ground it is necessary to convert this information into an understandable format for analysis and interpretation by the principal investigator. On-orbit preformatting of the data minimizes the latter task. These various requirements for handling the measurement data were grouped into a data management element, and a functional flow diagram (Fig. 5-1) was created to indicate their interrelationship. Each of the gross functions on this top level diagram was subdivided into more precise functional requirements from which specific items of equipment were definable. Where a function provided alternate choices for subdivisions or alternate choices for equipment to fulfill that function, tradeoff studies were performed.

Figure 5-2 presents an equipment block diagram of the entire data management system as evolved from the functional flow diagrams and associated design requirements. Signal flow between each of the equipments and to and from the spacecraft is indicated. Technically, the dynamic physiologic monitor is not an integral part of data management; however, it contains the combined analog / digital (A/D) data recorder of the data management system, and it represents the nucleus of a growth or backup operational capability. Equipment of other IMBLMS elements that interfaces with the data management element is shown in the dotted blocks of Fig. 5-2. Interconnection with the biochemical station is currently not a well-defined requirement; however, more accurate transducers for the conversion of biochemical phenomena to voltage equivalents are under development, and the need for meeting their potential interface requirements cannot be overlooked.

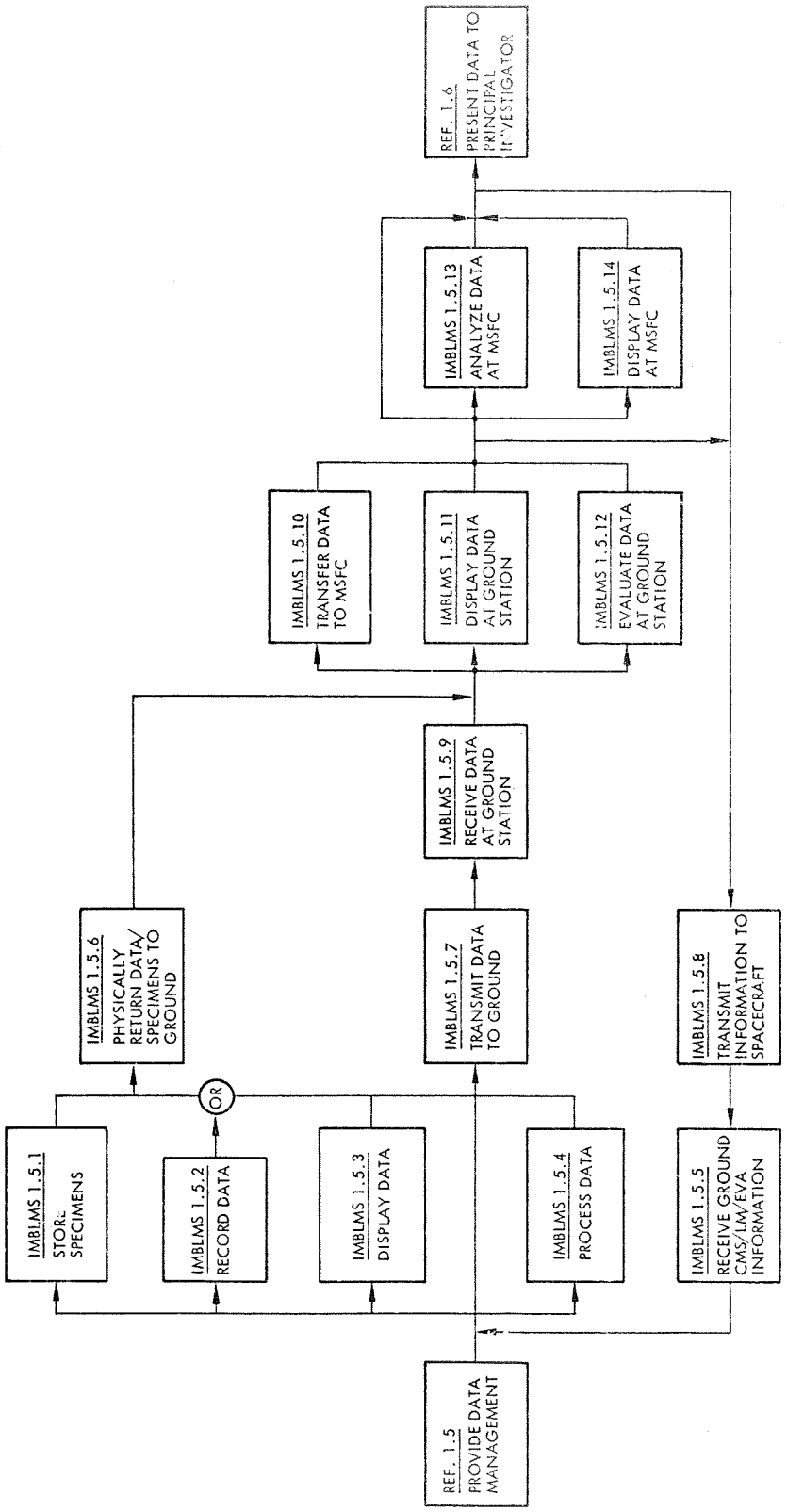


Fig. 5-1 Provision of Data Management – Function 1.5

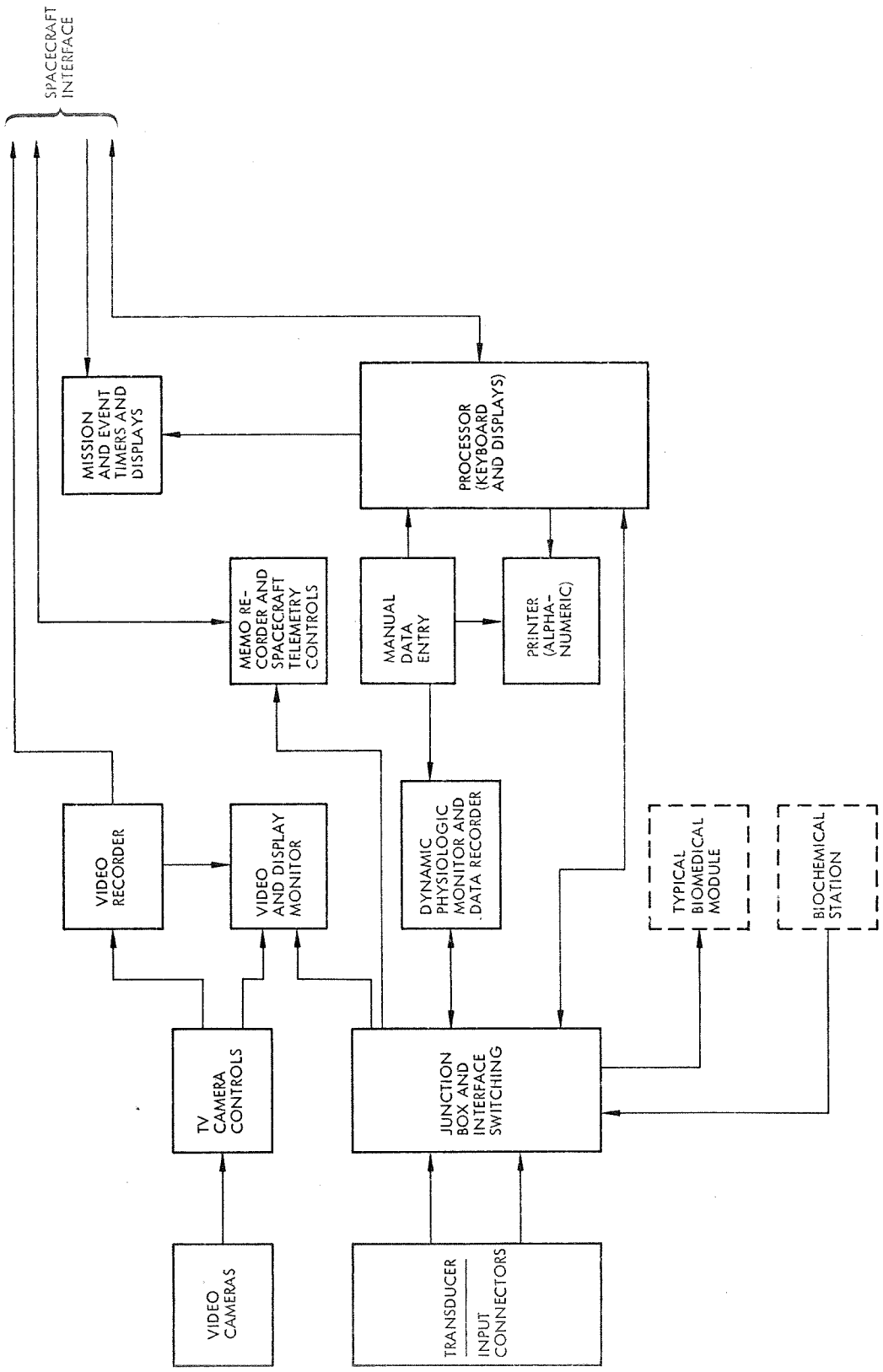


Fig. 5-2 Data Management System – Equipment Block Diagram

Figure 5-3 presents a front view of the data management modules. These modules include the following equipment:

- Video cameras and a microscope
- Video recorder
- Combined video and oscillographic display monitor
- Numerical data entry panel
- Memo recorder
- Digital data processor with input keyboard and associated displays
- Timers
- Spacecraft telemetry controls
- New combined analog/digital magnetic tape recorder (previously indicated as a submodule in the dynamic physiologic monitor).

All of this equipment is not needed to support an IMBLMS which might have very limited measurement requirements (e.g., safety or clinical monitoring only in contrast to a comprehensive measurement and analysis capability).

The dynamic physiologic monitor, by virtue of direct input connectors and its tape recorder, can display and record (jointly or independently) blood pressure, heart rate, EVA suit pressure, suit coolant flow, pCO_2, and body temperature. This module is portable and also contains its own calibration/monitor oscilloscope. Other biomedical modules will also be designed with direct sensor input connectors to permit backup operation in the case of a data management system malfunction. Independent use of the dynamic physiologic monitor and the vascular dynamic module will provide a partial clinical monitoring capability.

5.1.2 Growth Potential

Growth from this basic configuration can be accomplished through the addition of a processor module and associated junction box with interface switching. This addition can provide a gross improvement in the on-orbit capability for processing and displaying

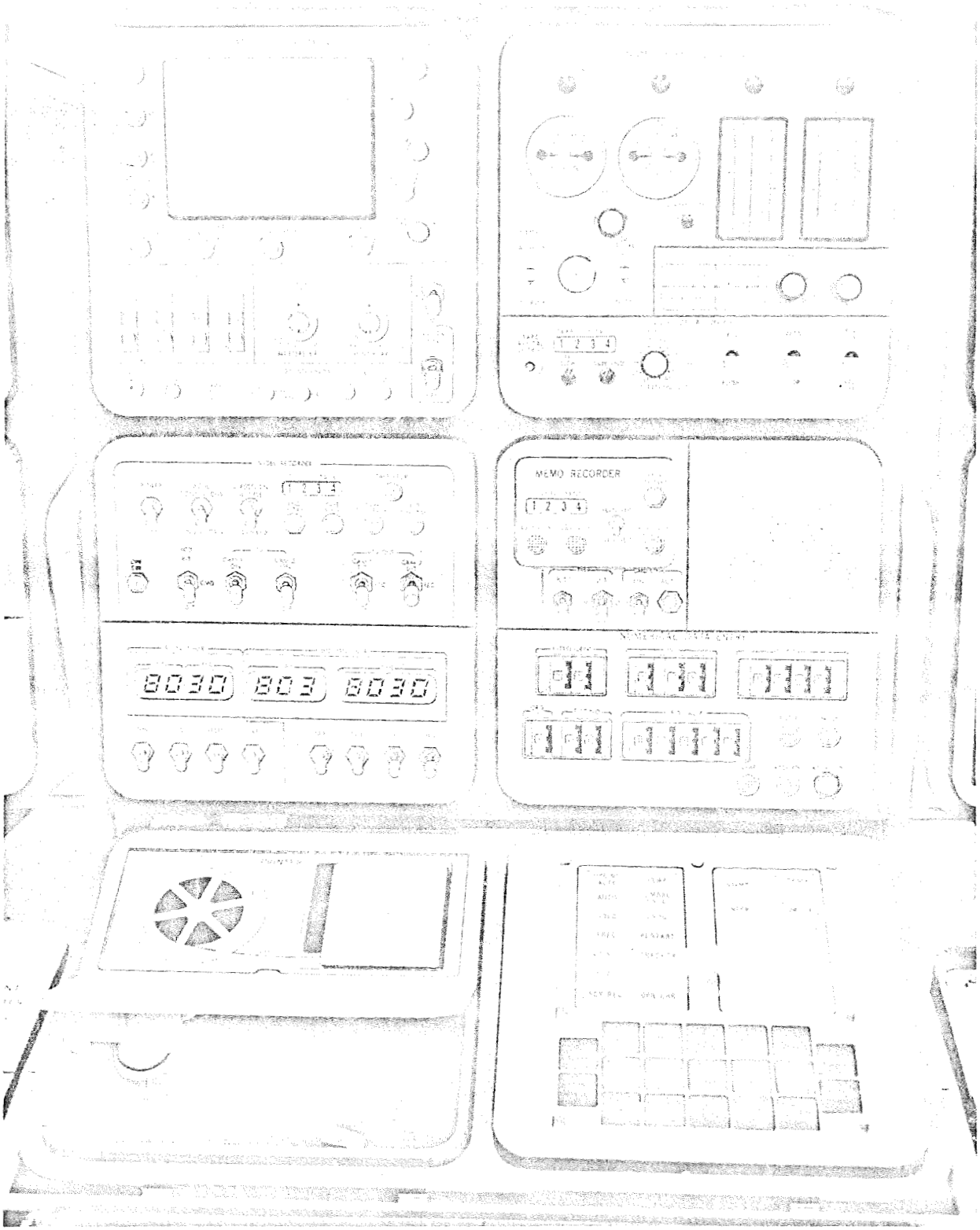


Fig. 5-3 Data Management Controls and Displays

data. Transducer inputs can thus be very accurately sampled, converted to a digital format, and then displayed on one of the three digital displays associated with the processor. These very accurate readouts – in the range of 0.1 percent rather than the 1 to 5 percent attainable with analog and FM/FM techniques – can be recorded and returned to the ground in digital form. Computations, calibration curve fitting and correction, removal of redundant data, etc. will be possible. Various measurement programs can be stored in the processor memory to aid in electronically routing input and output data, and activated by a simple entry of the appropriate measurement identification at the processor keyboard. Further growth will be possible through addition of the video system, thus permit the on-board recording of microscope images and other visual observations and their returned to the ground prior to the end of a mission. The visual monitor associated with this system also provides four channels of standard oscillographic display, besides serving as a key element in several behavioral tasks.

Addition of the numerical data entry module, together with an alphanumeric printer, enhances the recording of biochemical data and improves considerably the efficiency of the ground-based Principal Investigator to provide the astronaut with such information as digital uplink instructors or program changes.

A memo (audio) recorder has been added to improve the "no-hands" experimental data logging for later playback and entry into the system. Located just below the memo recorder is a set of controls for remote operation of the applicable spacecraft transmitters. These controls are designed to operate with the AM transmitters; however, adaptation to the USB transmitters in the CSM will be a relatively simple task.

More detailed discussion of the various data management equipment capabilities, needs, and uses, and related development status and cost aspects, are presented under specific equipment heading in the remainder of this section.

5.2 DATA MANAGEMENT AAP SPACECRAFT INTERFACE

The data acquisition~recording capabilities in both the AM and OWS carriers were considered for IMBLMS use. The VHF transmitters proposed for these carriers were considered along with the possible use of one of the USB transmitters in the CSM. The bandwidth available with the USB transmitter permits the transmission of normal-scan or recorded and speeded-up slow-scan television pictures to the ground. Use of the CSM S-band transmitter is the recommended approach.

5.2.1 Experiment Data Acquisition System

The current experiment data acquisition system (EDAS) concept provides inputs to a modified AM pulse-code-modulation (PCM) system with modified PCM recorders. The PCM multiplexing format provides 2 or 3 channels with 320 sample/sec capability. The recorders were modified from dual digital-track units to one digital-track and one voice (analog) track unit, primarily to sample and record cardiac signals which require bandwidths of 0 to 100 Hz. Unfortunately, there is insufficient sampling/recording capability in this system to handle the simultaneous nine to ten 0-to-100 Hz input channels together with some 47 other inputs required during an IMBLMS LBNP determination.

5.2.2 Experiment and Housekeeping Data System

A new experiment and housekeeping data acquisition system concept is presently approaching development and Cluster application. This concept provides a much higher speed sampling with random access multiplexing capability expandable from 64 to 1,024 analog inputs. Inputs from this system, following IMBLMS growth from its basic analog configuration to a digital system, would be very useful, although the mixing of experiment data with housekeeping data creates ground decommutation and handling problems. In view of these potential problems, the IMBLMS design will parallel the new concept with an IMBLMS multiplexing capability, except that fewer

channels will be provided. Should this potential problem area prove surmountable, utilization of the new data system can be readily implemented.

5.2.3 Experiment Support System (ESS)

This system, now in a conceptual stage, will provide the eight approved AAP experiments with a central location for such components as stored electrodes and harnesses; an electrode checkout device; utility monitoring and control; an automatic, blood-pressure, cuff-inflation unit; blood-pressure (systolic only) readout; and heart-rate readout. Since the ESS is designed only for early experiment support, it is recommended that the displays and other components, as applicable, be repackaged into the IMBLMS configuration.

The AM will have 96 real-time digital command functions on its UHF receiver (up-link) of which 18 are presently unassigned. The IMBLMS, with aid of additional encoding, will use these 18 command channels for the transmittal of experiment change and correction instructions, operation of an on-board digital printer for a communication link other than voice, and ground control of IMBLMS recorder readouts and other data.

5.3 DATA MANAGEMENT RECORDERS

Provision for recording information is an essential aspect of three IMBLMS techniques for obtaining required measurement data. These techniques include analog-type data for various biological parameters, which are recorded directly or converted to digital (PCM) format (for storage and later transmission to ground); a memo-recorder (i.e., verbal "scratch-pad") enabling the astronaut to dictate notes for later playback and use; and the recording of video images by the IMBLMS TV camera system.

The analog-to-digital (A/D) recorder will be a 3-speed, 14-track unit with playback capability. Various transducers will receive stimuli from up to 58 distinct physiological and environmental sources and this information will be recorded on 12 of the 14 available recorder tracks, either directly or in an FM-multiplexed or commutated

mode. The two remaining tracks will be utilized as a lock (for ground station synchronization) or for audio data (i.e., subjective comments made by the astronaut during tests). The video recorder is discussed subsequently in Section 5.6.

To implement the recording of 58 simultaneous data inputs (channels) on the 12 available tracks, FM multiplexing and PCM techniques will be used. The FM technique allows many channels of data to be recorded on a single analog track by using direct recording with a high frequency a-c bias. In the full system configuration (non-portable) each data input will be sampled at discreet, rapid intervals; converted to PCM; and recorded. Data inputs can also be displayed on the monitor/oscilloscope while being recorded to verify transducer operation and recorded status. To permit portable operation, four of the 12 tracks will be retained for recording direct analog data (using IRIG FM techniques) and the other 8 will record digital data. Channels carrying data with a slow rate of variation (e.g., skin temperature) will be subcommutated at a much slower rate, and injected into the sampling train at longer intervals. All data will be dumped on ground station or spacecraft command. The astronaut will be able to change tape reels easily should retention of a particular reel be desired.

The memo (scratchpad) recorder provides 1 hr of voice recording at a tape speed of 1 ips. It will be compatible with the astronaut microphone and earphones so that he can record or play back verbal notes at any time. Reels can be easily changed to retain particular notes or to provide, perhaps, audio stimuli for various behavioral tasks.

5.4 DATA MANAGEMENT PROCESSOR AND INTERFACE SWITCHING

Major aspects of the requirements for this aspect of the data management system include an acquisition and processor function, modular growth, display capability, and interface switching.

5.4.1 IMBLMS Processor

IMBLMS requirements indicated the need for a data acquisition system and digital data processor to evaluate and convert incoming analog signals for display and/or

transmission to the ground. The processor, in its basic configuration, will perform as a data compressor for reducing the total data for transmission or storage by eliminating redundant data.

Inputs to the processor will consist of 256 channels of either analog or 8-bit digital words. The analog data are multiplexed (sampled) and forwarded to an 8-bit A/D converter. The output from the converter is then multiplexed with the 8-bit digital words and delivered to the processor.

The analog multiplexer will be designed with three levels of analog gates. Operational amplifiers will be used after the second and third levels. A zener diode is used at the inputs of each of the operational amplifiers to prevent the amplifiers from going into saturation if a multiplexer input channel has an open connection, (e.g., an electrode disconnecting from the astronaut.) Programming of the processor will allow the selection of the desired data compression algorithm.

A general purpose airborne computer could handle these requirements, but would require an expanded multiplexer and excessive time for the removal of redundant data. Most computers of this type do not have provision for modifying the program while in orbit. Design of a special compressor/processor will best meet IMBLMS requirements.

5.4.2 Modular Growth

A modular expansion capability designed into the processor will allow an easy conversion to a full computational capability. Additional tasks can be performed with this add-on capability, such as data conversion for alphanumeric display, recall of previously processed data for on-board analysis, and acceptance of ground instructions for display and program correction.

5.4.3 Display Capability

Three digital displays will be provided for read-out in measurement units for various measurements. Alarm conditions will be easily detectable, and the astronauts will be alerted by visual and auditory means. Display of other less important spacecraft and measurement information can be provided by commands from the processor keyboard. Digital values loaded into the various memories will be displayed before loading and may be unloaded for program verification.

5.4.4 Interface Switching

The numerous sensor inputs and the interconnects from external equipment must be easily connected to the PBDM station modules. The A/D tape recorder and the processor must have signal access to the various modules and many intramodule connections will be required. Since a few of these connections need be permanent, the various interconnecting lines can be efficiently shared by incorporating a switching network.

A trade study comparing manual versus automatic switching indicated that an electronic switching system, controlled by the processor, is essential to performing these complex switching functions, and to maintaining astronaut tasks at a reasonable level. The electronic switching network will be controlled by commands from the IMBLMS processor, and will allow switching connection commands in the processor memory to be easily altered on the ground or on-orbit, when required meet changes in test philosophy and requirements.

Each station module will require power connection, and several have water and air-pressure connections. The electronic switching network is incorporated in the junction box to provide optimum switching capability with a minimum of module interconnections, and to allow later modification of planned experiments and switching-network storage commands.

5.5 DATA MANAGEMENT MANUAL DATA ENTRY AND PRINTER

Many biochemical measurements will require system entry of numerical data for recording and for recording and for intermittent test data analysis. This information will be recorded for delayed transmission to ground or transmitted on a real-time system. The data may also be printed on tape at a remote location (e.g., the proposed LM teleprinter) or at a printer located in the IMBLMS station.

A trade study was conducted comparing the results of using a remote printer, an on-station printer, or none at all. The outcome was a recommendation for a line printer located at the PBDM station and providing an on-board hard copy of the intermittently entered numerical data which yielded a continuous record of the experiments. The accuracy of recorded results and systems reliability will be further enhanced by permitting the printer to serve as means of displaying ground commands and computer output results. A remote LM printer could also yield a hard copy of the test data, but it would not provide immediate visual verification of input data. Further, the LM printer may also used for many other functions, and the IMBLMS data could easily be obscured by other printed information.

The actual process of manual numerical data entry requires simplicity of execution, high reliability, low time consumption, and possibly redundant data elimination. Five configurations were studied, including handwritten data; a combination of thumbwheel, digit dial switches, and line printer; the Apollo keyboard; a card reader system; and a typewriter keyboard.

The least complex method – handwritten data – presents the greatest difficulty in supplying reliable flight information to the ground, since it will have to be transmitted by voice. The more complex methods, such as the Apollo keyboard, require new hardware development, are more expensive, and add to the astronaut manipulation burden. Consequently, the combination of thumbwheel, digit dial switches, and line printer was selected for IMBLMS data management purposes.

With this method, numerical test information is entered by means of digit switches on the data entry panel. A "print" command results in a verifying printed tape which also serves as the on-board hard copy. Errors may be corrected with a "clear" command, and a new entry may then be printed out. An "enter" command records the data while a storage buffer retains the information for comparison with the next entry to provide redundant data elimination when desired.

5.6 DATA MANAGEMENT VIDEO SYSTEM

The data management video system will serve as the on-board sensing, display, and recording media for information pertinent to various biological, physiological, psychological, and physical measurements, functions, and activities of the astronauts. Without some method of visual sensing or display, a serious degradation of both quantitative and qualitative information necessary for a thorough evaluation of mission success will occur. Precise hematological, urine, and microbiological examination will be delayed until the end of the mission if a qualified laboratory technician/astronaut is not available on-board the spacecraft. Even the presence of a qualified astronaut may not eliminate the need for presenting real-time data to a ground-based principal investigator. Close examination of astronauts while performing ergometer, LBNP, and routine cabin activities, or for time and motion studies, will be required on a real-time basis to obtain meaningful and complete data on astronaut performance.

Consideration was given to the sole use of motion-picture cameras to supplement the nonvideo electrical sensors but this was rejected on the basis that photographic information would have to wait until the end of the mission for evaluation. However, such cameras, if available on-board the spacecraft, could function as a very useful adjunct to a video system.

A video system is therefore recommended as an essential equipment for inclusion in the IMBLMS. Such a system, to provide comprehensive coverage of all the parameters involved, will encompass the following subsystems:

- Cameras (2) – 2.5 in. by 10 in., approx. 3.5-lb wt (ea.), with camera control unit (8 in., approx 25-lb wt) supplying power to and process signals from both camera heads
- Combination video-monitor and oscillator display unit
- Video recorder with playback capability

The subsystem interconnect will permit the video images sensed by the cameras to be displayed on the monitor, recorded on the tape recorder, or sent directly to the ground.

Each camera will have a distinct function, but these functions will be interchangeable in case of failure of either unit. The camera that interfaces with the microscope will operate at 0.625 frames/sec with a resolution of at least 1,050 scan lines. Since the frame/line rate is a function of bandwidth and will be designed within limited bandwidth constraints (i.e., for use with CSM USB equipment), the frame rate must be lowered to provide high resolution for a maximum medical/biological analysis capability. The second camera will operate at 10 frames/sec with a reduced scan rate of 525 lines, again to stay within bandwidth limitations. This second camera will observe the astronauts in the performance of their various tasks, tests, and functions, and a higher frame rate therefore must be used in viewing this area of potentially greater activity (in contrast to the observation of semipassive microscope specimens).

Both cameras will interconnect with a single control unit. The camera control unit interfaces with both the videotape recorder and the monitor/oscilloscope to provide individual or simultaneous video signal inputs.

The videotape recorder performs a dual function. It not only receives video input information for recording but is capable of playing back preprogrammed tapes containing behavioral tasks and tests for display on the monitor. The recorder (4.5 in. by 9 in. by 14 in. in size), will provide a minimum of 24-min recording/playback time and be able, upon command, to dump the recorded video information to a ground station.

The astronaut will be able to exchange tapes and insert the behavioral tapes at whatever time is specified in the mission schedule.

The integrated video-monitor/oscilloscope will display the video images prior to or during recording. It also will display, on a time-sharing basis, up to four analog or digital (in PCM form) channels of data from the A/D recorder to permit verification of the recording. The monitor is a 7 in. by 6-1/2 in. by 15 in. in size, weighs 20 lb., and will be primarily used for visually checking the focus and clarity of the specimen slides in the microscope/camera setup before camera recording is initiated. Recordings in the active area can be similarly verified. A dual persistence feature will allow either image or traces to be displayed for long as well as short periods.

5.7 GROUND NETWORK CONSIDERATIONS

Much of the physiological data, and some of the biochemical data (e.g., white blood-cell count), should be in the hands of a ground-based principle investigator in near real-time. These data relate primarily to astronaut well-being and safety. If one of the astronauts is also a trained physician, it becomes more important to provide accurate, complete data by means of the on-board equipment. Data relayed to the ground in the latter case loses some of its urgency. Nevertheless, this provision does allow for back-up diagnosis, more thorough trend analysis, and quicker ground response for possible measurement modification.

Most real-time data, to be of immediate value, must be transmitted directly to MSC, KSC, or Corpus Christi for analysis and evaluation. Data transmitted to other ground stations will have to be recorded and then forwarded by whatever transportation is available to MSC, KSC, or Corpus Christi for similar purposes. The related delay thus removes the transmitted data from its real-time category.

The combination of IMBLMS data with spacecraft-housekeeping data, as previously mentioned, creates two problems. First, this method takes longer to extract the IMBLMS measurement information from a data stream and, second, it requires additional equipment. A solution is available with the IMBLMS data management capabilities. The IMBLMS processor can provide the data to the IMBLMS recorders and, ultimately, to the spacecraft transmitters, in various formats. One format accelerates ground handling of IMBLMS data (not combined with spacecraft-housekeeping information) whereas another format (simultaneous) simplifies on-board display and measurement evaluation.

In view of the foregoing considerations, it can be seen that the IMBLMS data management system, through its growth capabilities, complements both on-orbit measurement flexibility and ground-based, data-handling requirements.

Section 6
SYSTEM ENGINEERING

6.1 GENERAL

The overall MBLMS concept consists of the following major elements:

- Physiological/behavioral/data management station (PBDM)
- Biochemical station
- Major peripheral measurement equipment
- Storage capability for small equipment items and expendables

Major items applicable to both stations are individual modules, module storage frames, protective covers, MDA support frames, and OWS ground-fitted support frames.

6.2 OVERALL DESIGN CONCEPT

The PBDM station incorporates five measurement modules organized around body organ functions, five data management modules, a support storage module for peripheral equipment, an interface and distribution system module that permits signal pickup from remotely located peripheral measurement equipment (and which provides hardwire connection for stowed biomedical harnesses), sensors and signal conditioners, and a junction box that permits the distribution of signals and and provide a separate routing for on-board power. Auxiliary support such as water, vacuum, and air pressure is provided by spacecraft supply and will junction directly with the module involved.

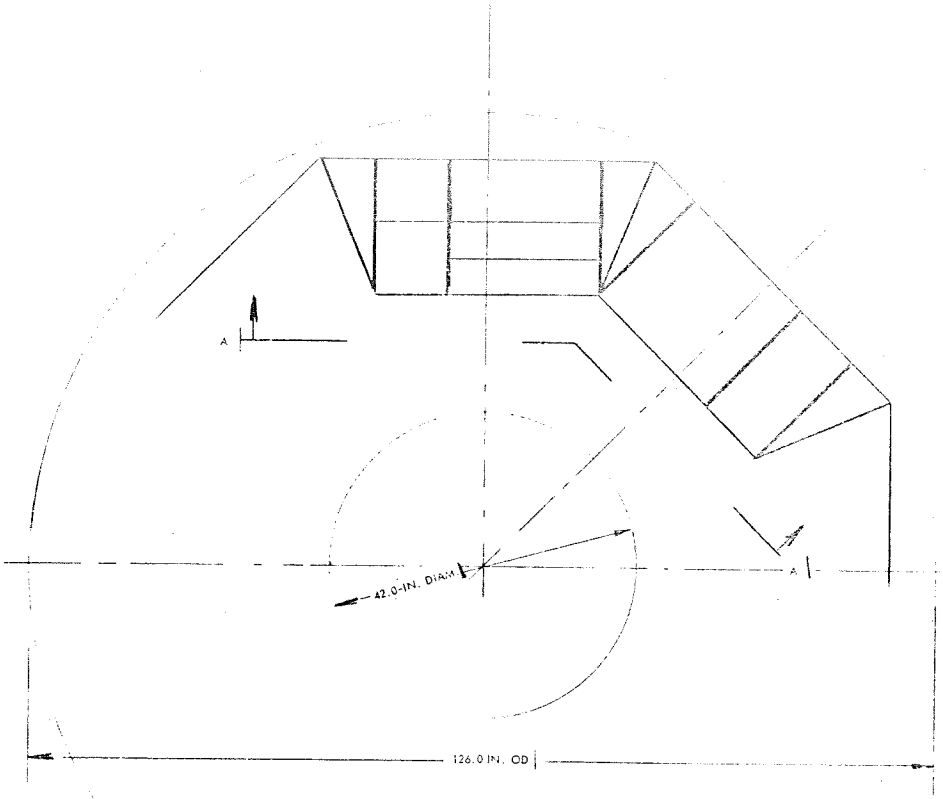
The Biochemical station requires four modules used for biochemical analysis and isotope monitoring, and for incubation purposes. It also requires two modules for use, respectively, as a waste collection compartment and a storage space for a

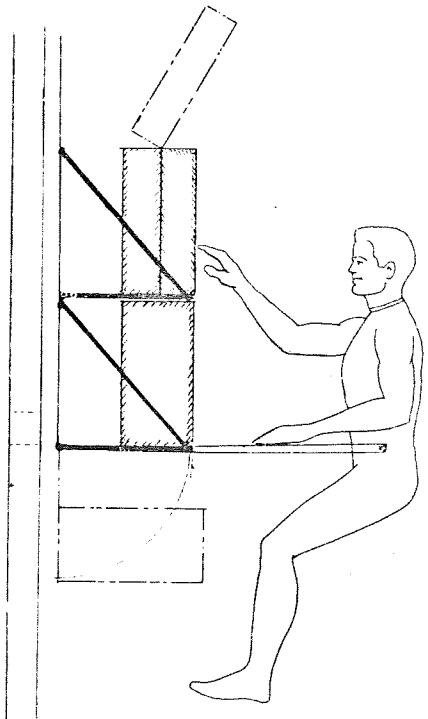
microscope. A separate module is employed as a freezer unit, and a nonstandard module serves as a supply storage container and as a housing for the centrifuge.

At launch the individual modules are stored in single or two- or four-module storage frames, depending on transportability requirements. These storage frames, as shown in Fig. 6-1, are housed in welded tubular MDA support frames held in level position by tension members which are provided with a vibration damper (Fig. 6-2). Vibration isolation is required for this type of installation due to the launch environment of the Saturn V Launch Vehicle.

For the S-IVB OWS, LMSC recommends locating the PBDM station in the Crew Experiment Compartment (No. 1) and the Biochemical Station in the Waste Management Area Compartment (No. 3). (See Fig. 6-3.) The modules transported from the MDA in single or two- or four-module units are mounted to a welded tubular frame which has been ground-fitted to the OWS. The frame in turn is mounted on a set of rails pre-installed on the grid-patterned OWS floor. The rails permit sliding the stations away from the wall so that the crew members can easily reach behind the station for access to cables and plumbing.

Peripheral equipment items are categorized by their location with respect to the IMBLMS. Some peripheral equipment (e.g., the VCG, ECG, and blood-pressure cuffs) is located in an adjoining interface and distribution system module. This permits hard-wiring and direct interconnection to the junction box. Other peripheral equipment, such as the TV camera, is stowed in the printer module for easy operator access. A major proportion of the peripheral equipment (e.g., the rotary chair, mass measurement system, and ergometer) will be stowed in individual canisters. The IMBLMS is arranged so that this peripheral equipment can be brought up to either side of the station and, in some cases, in front of the unit. The IMBLMS provides interconnection and distribution for all peripheral equipment, augmented by display and recording functions when required.





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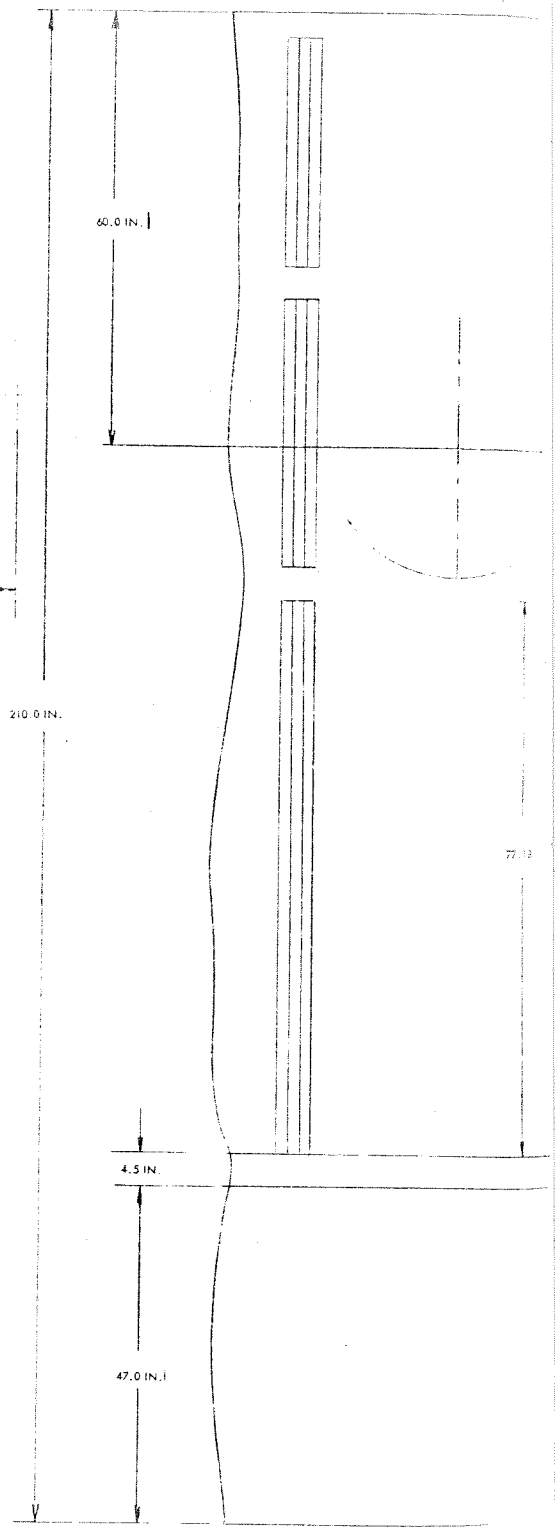

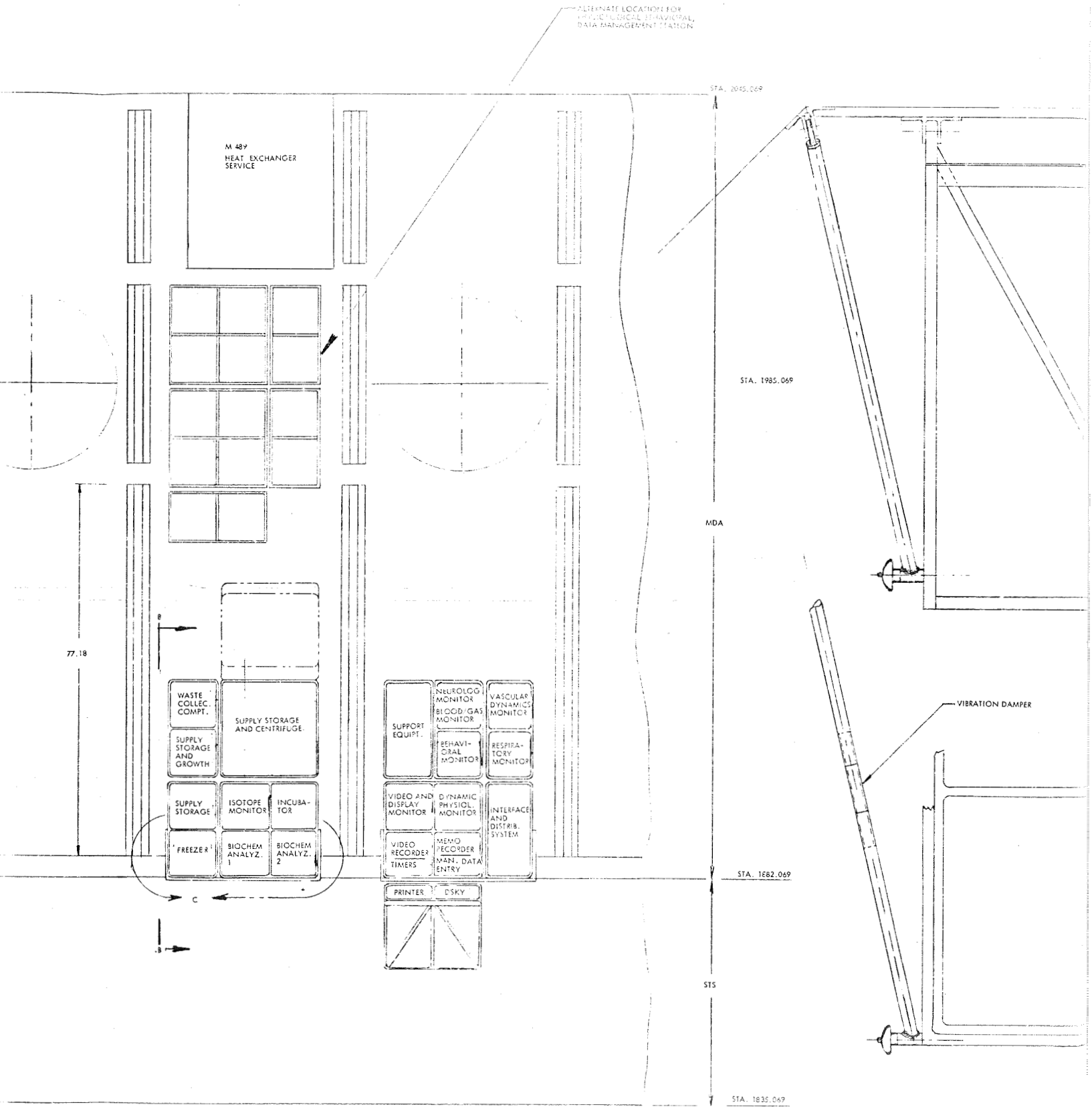

VIEW A - A
(UNFOLDED IN FLAT PLANE)

6-3a

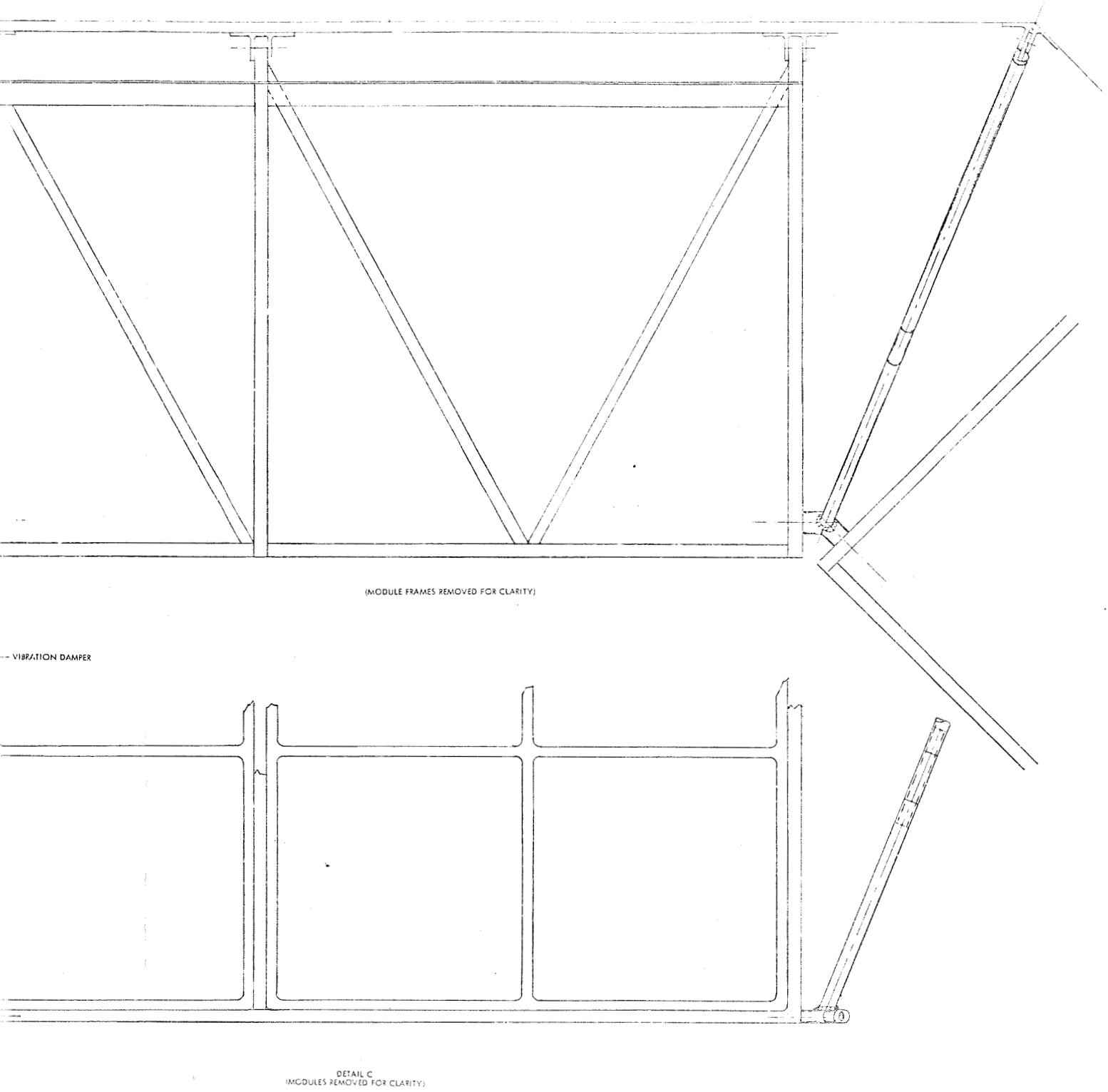

Fig. 6-1 Arrangement for IMBLMS/MDA Installation

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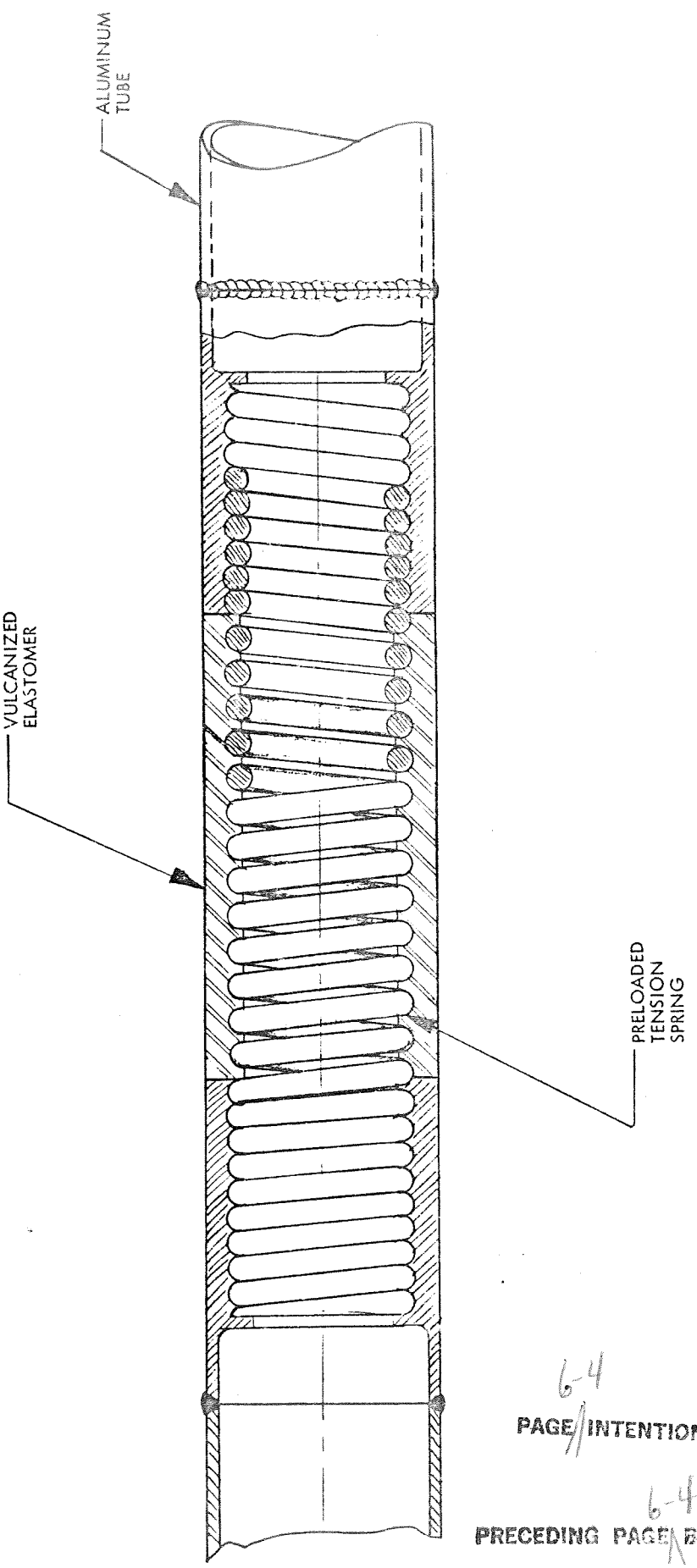

Fig. 6-2 Vibration Damper for IMBLMS/ MDA Installation

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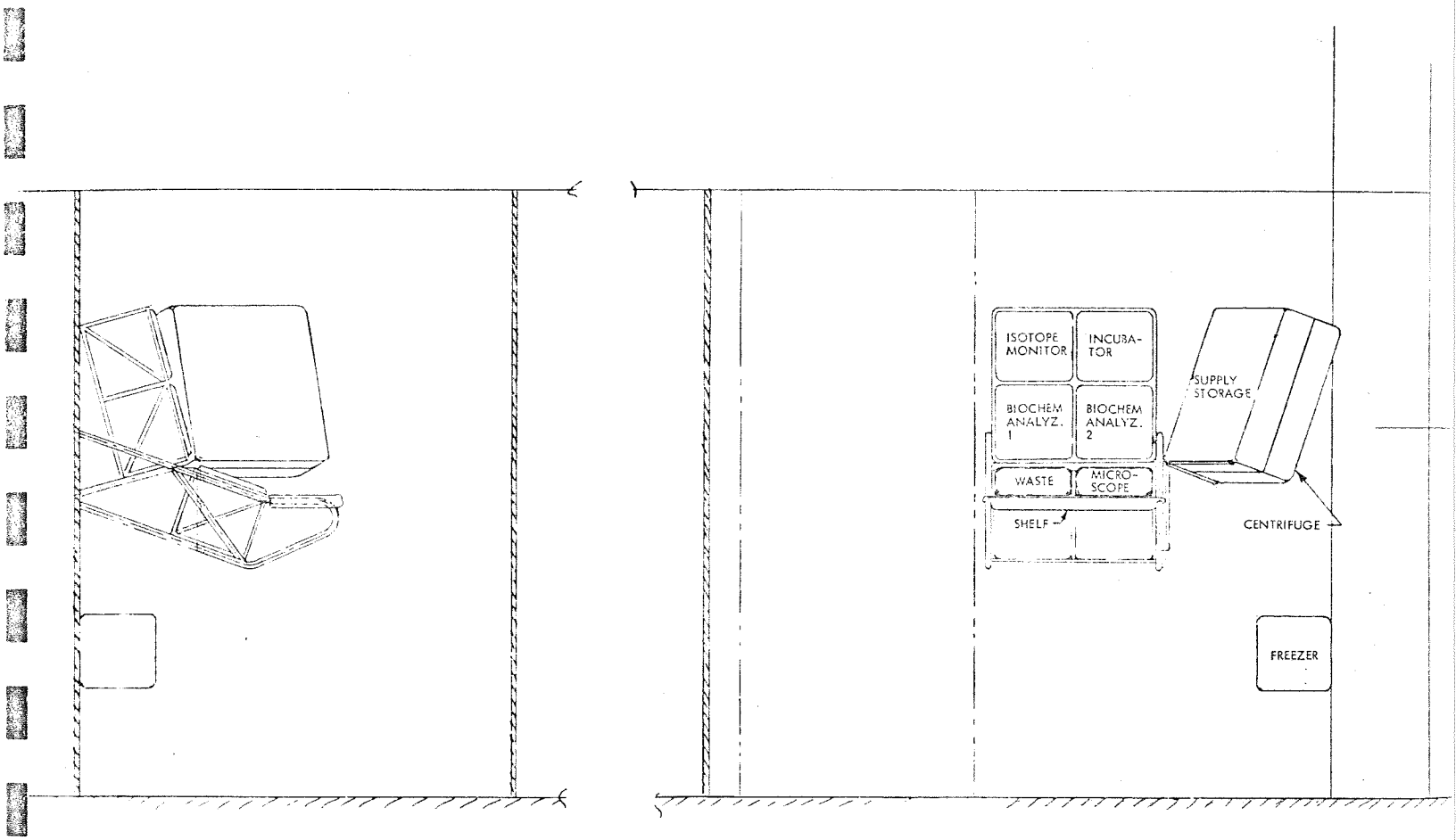
6.3 ENGINEERING REQUIREMENTS SUMMARY

The establishment of engineering requirements requires the examination of all factors that influence the IMBLMS design concept. A flow diagram reflecting the system engineering approach that was followed is shown in Fig. 6-4. This approach is organized around the special study requirements specified for the Phase B, Section II effort. It does not employ the detailed Phase C analytical studies, which will include thermodynamics, structures, loads, and dynamics; however, it does examine closely the special problems associated with IMBLMS and the particular interface areas associated with AAP. As shown in Fig. 6-4, the initial inputs were the previous efforts and definitions afforded by IMBLMS Phases A and B, Section I.

The AAP general experiment specifications and the design standard bulletins issued by the Manned Spacecraft Criteria and Standards Board were reviewed for applicability and the pertinent items included in the Master Requirement Allocation Sheet (MRAS) with the emphasis on the specific approach to be used in the IMBLMS program to meet the stated requirements. Engineering data gathered during the study were attached to the MRAS and governed the design effort in terms of developing equipment block diagrams and station layouts.

Major engineering requirements established were as follows:

- Grouping of measurement equipment in accordance with a specific body organ or class of measurement
- Centralizing data management and control so that storage, recording, display, evaluation, and control can be accomplished for all modules
- Physical separation of physiological/behavioral measurements from biochemical measurements, and provision of a filtered compartment for those measurements involving liquid or gas
- Provision for interconnect and distribution at the centralized PBDM station for all peripheral measurement equipment, such as the LBNP, ergometer, and mass measurement system



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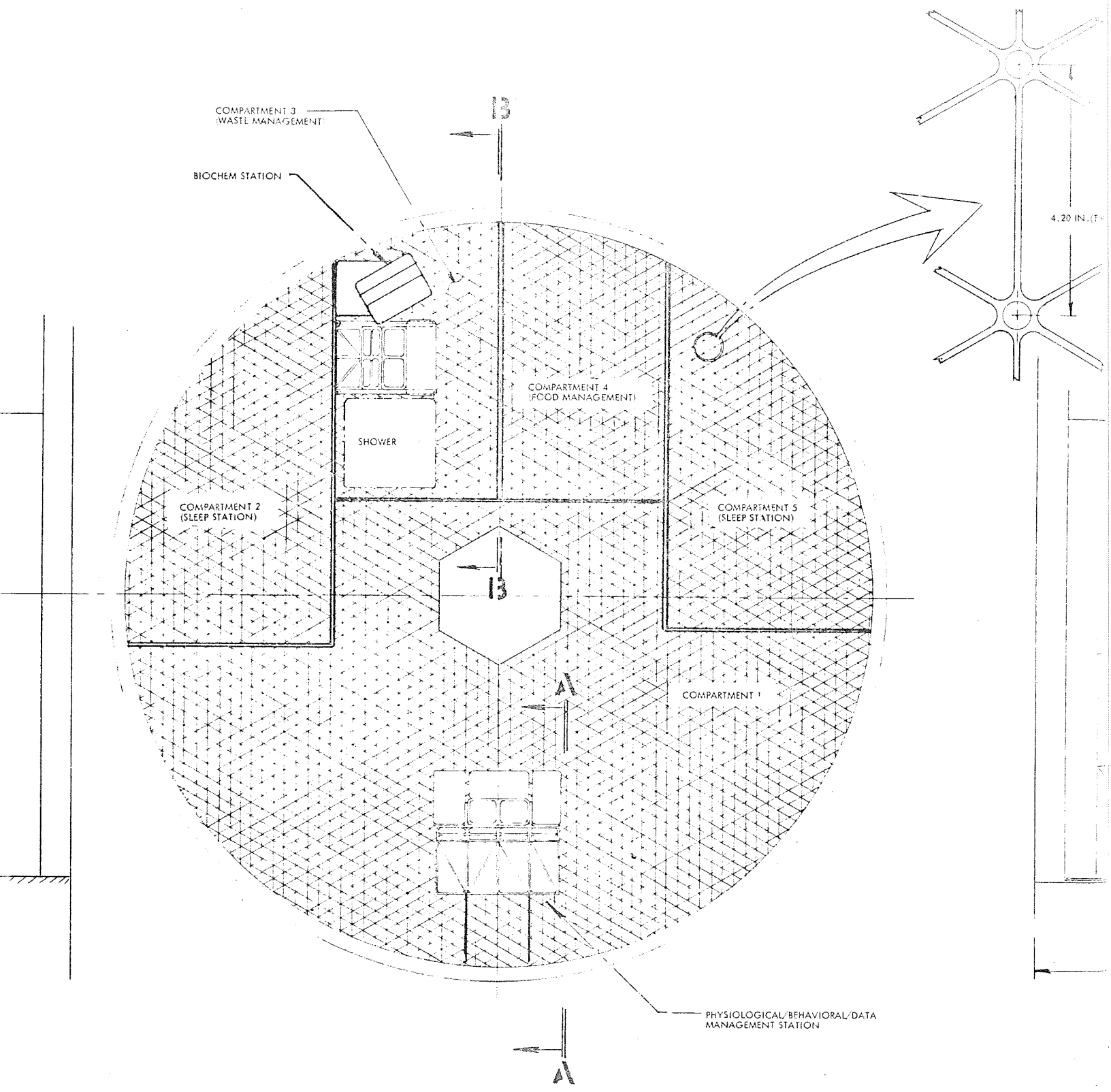
COMPARTMENT 3
(WASTE MANAGEMENT)
BIOCHEM STATION
B
B
A
A
SHOWER
COMPARTMENT 4
(FOOD MANAGEMENT)
COMPARTMENT 2
(SLEEP STATION)
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COMPARTMENT 1
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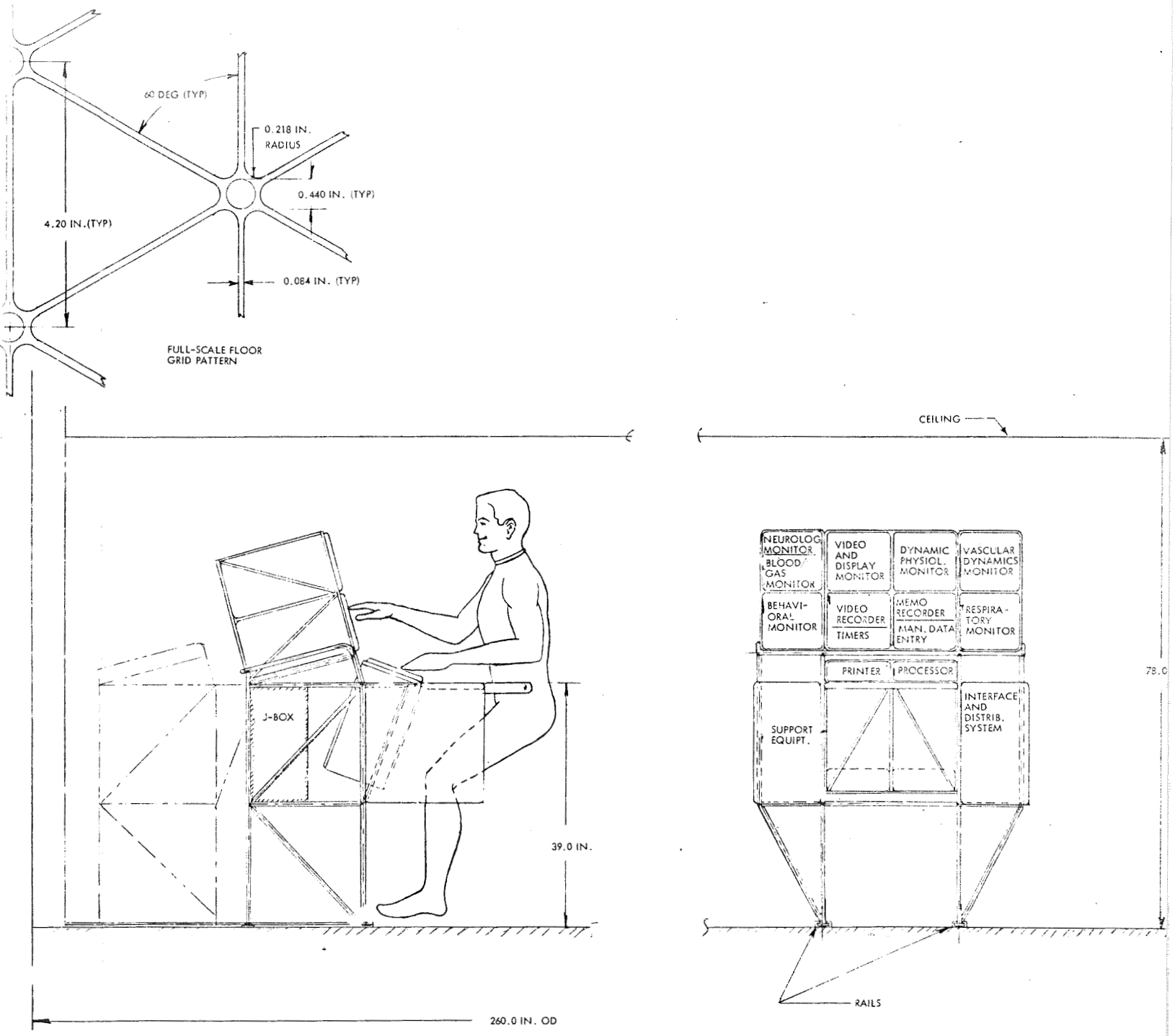

Fig. 6-3 Arrangement for IMBLMS/OWS Installation

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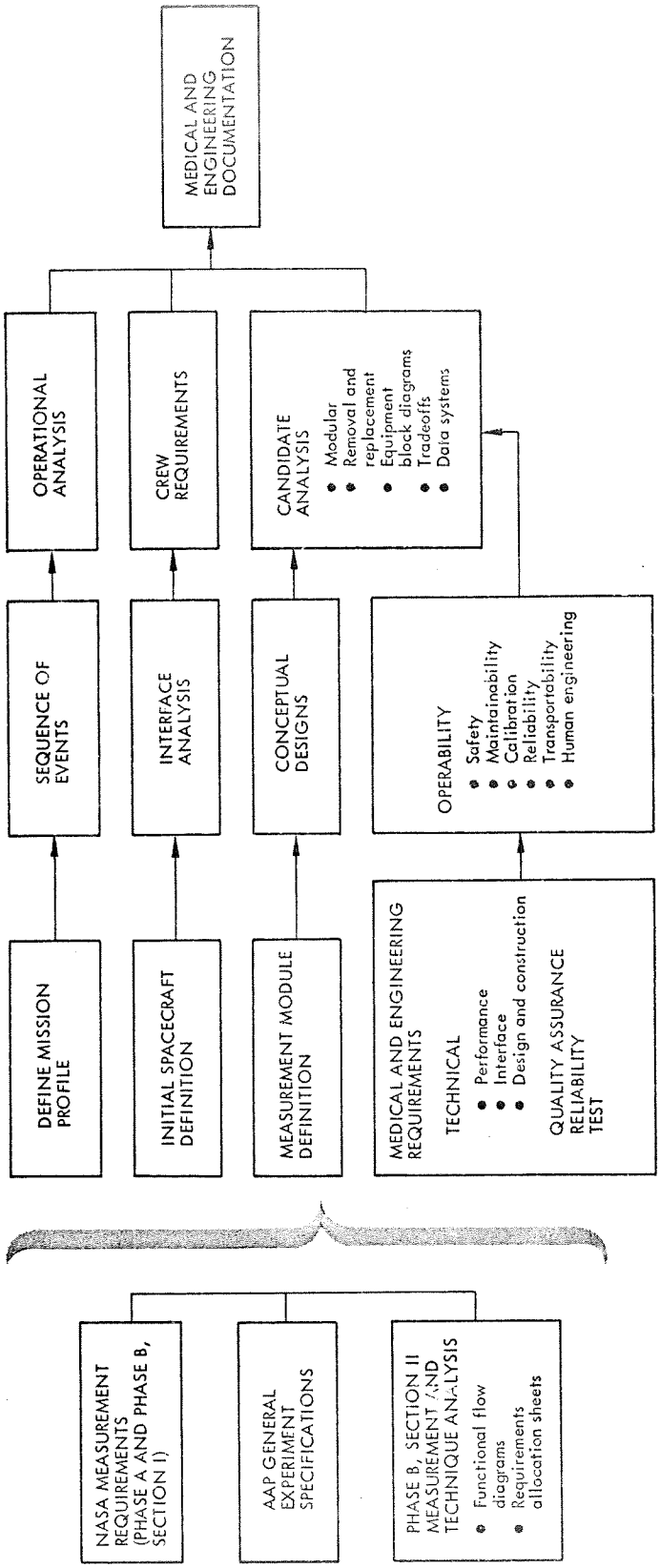


Fig. 6-4 IMBLMS System Engineering Flow Diagram

- Prelaunch installation capability in the RCM, LM-Lab, and MDA
- Prelaunch installation of station support frames in the OWS
- Volume/mass factor consistent with transporting modules from the MDA to the OWS
- Standard modules, defined as integrated plug-in units measuring 9.5 by 9.5 by 18 in. for the PBDM station and 9.5 by 9.5 by 9.5 in. for the Biochemical station
- Nonstandard modules to be dimensioned multiples of the standard PBDM module and similar in depth
- Submodules defined as (1) simple replaceable components of a module or (2) small functional unrelated units measuring half or quarter of the standard size and varying in depth, but not exceeding the maximum of the affected standard module
- Submodules to be removed and/or replaced only when the affected standard module is removed from its mounting

6.4 EQUIPMENT BLOCK DIAGRAM

The equipment block diagrams are used to accomplish the transition from functional orientation, as depicted by the functional flow diagrams and the design requirements of the requirements allocation sheets, to equipment orientation. Requirements for calibration, alarm, computation, maintainability, and reliability must be resolved prior to creating equipment block diagrams. These diagrams are organized around the individual modules required for specific body organ measurements, summarize major components, and illustrate their interfaces with the complete system. They permit, in turn, the initiation of the next detailed design step of determining electrical wiring requirements, harness layouts, and detail schematics and design layouts. A typical example of an equipment block diagram is shown in Fig. 6-5, which indicates the major components required to conduct dynamic physiologic monitoring.

The functional flow diagrams and the system engineering analysis that preceded the equipment block diagram are key engineering tools. The dynamic physiologic monitoring imposes unique requirements on the block diagrams since it requires intrastation and EVA provisions.

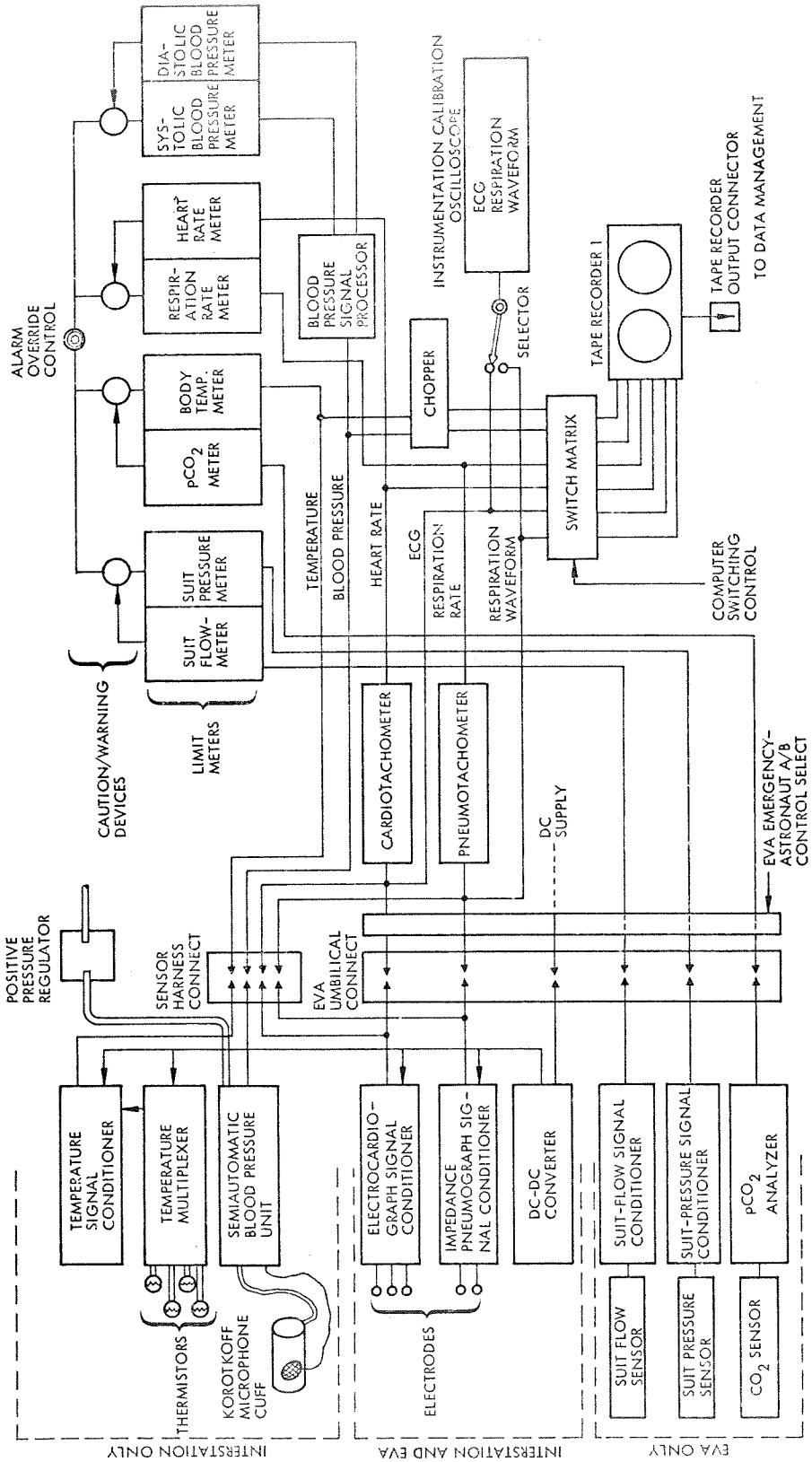


Fig. 6-5 Dynamic Physiologic Monitor – Equipment Block Diagram

The top group of sensors which are shown in Fig. 6-5 for intrastation use are linked closely together. Sensor harness connection for this peripheral equipment is shown as a separate connection distinguishing it from the EVA umbilical connection. The intrastation and EVA group utilize the same sensors as shown; however, the block diagram illustrates that separate harness connectors are provided. Computational requirements are shown for both cardiotachometer and respiration. The EVA-only category applies to sensors and amplifiers located on the EVA astronaut. Two operating modes are illustrated – hard-wire umbilical or near-field telemetry. Display and alarm circuits are shown linked to their respective signal conditioning equipment. An instrumentation calibration oscilloscope is shown for gross display of performance capability of individual signal conditioners, together with a signal generator provided for applicable calibration.

6.5 MAJOR ENGINEERING INVESTIGATIONS

Critical engineering areas were identified and analysis performed in those areas concerned with IMBLMS installation in the RCM, LM-Lab, MDA, and OWS. Module design analysis covered handling, maintainability, calibration, and electromagnetic interference.

6.5.1 Installation Considerations

Installation techniques considered were (1) initial storage in the MDA and subsequent transfer to the OWS for operation, (2) ground-fitted installation in the RCM and/or LM-Lab, and (3) initial storage in the MDA with a capability for operating the IMBLMS in that location or subsequently in the OWS. Consideration was also given to a completely dry-fitted S-IVB, and this alternative is discussed in Section 6.10.

Installation in the OWS. The installation of the system within the confines of the OWS shown in Fig. 6-3 is based on design requirements that the system will not be exposed to the launch environment within the OWS. The mounting frames, therefore, can be designed to an ultimate load of 1 g in all directions, or to the expected handling loads in an Earth environment, whichever is greater.

The PBDM station is located in the Crew Experiment Compartment (No. 1) and its modules are mounted to a welded tubular frame which is fitted into a set of rails installed on the grid patterned OWS floor. The empty tubular frame and the rails are installed in the OWS before launch and therefore experience the launch environment in only an unloaded condition. The rails make it possible to slide the station away from the wall so that the crew members can easily reach the rear of the unit for connection and disconnection of cables and plumbing, and for maintenance, thereby providing greater flexibility in the crew experiment compartment.

An alternate version of the pre-installed, tubular-frame design is a collapsible frame concept which would be carried to orbit in the MDA or RCM and, after purging, transferred to and installed in the S-IVB OWS. However, preliminary investigation indicates that this approach involves a weight penalty an increase in station setup time of.

Installation in the MDA. The installation frames for the Biochemical station and the PBDM station (Fig. 6-1) consist of welded tubular structures mounted against the inside of the octagonal payload mounting structure which is attached within the MDA by means of hinge pins. The frames are held in level position by tension members equipped with a vibration damper (Fig. 6-2). Vibration isolation is considered necessary for this type of installation because the equipment will experience the full launch environment, yet it cannot be mounted permanently by means of bolts or similar attachment because quick and easy removal and replacement are required by the orbital environment. Although the rear of the module faces the wall, quick connection and disconnection of electrical harnesses and plumbing can easily be accomplished by removing the ball-lock pins provided at the end of the tension members, and rotating the entire package 90 deg so that the rear moves to a top position.

If the mission subsequently calls for IMBLMS operation in the OWS, this removable type of installation provides the advantage that, after removal of all module units, the frames and tension members can be stored flat against the wall, leaving a fair amount of highly desirable empty space for astronaut movement in the MDA. When operation of the IMBLMS in the MDA is not contemplated, i.e., when the MDA is used only

as a transportation medium for the system, the alternate location for the PBDM station, as shown above the Biochemical station in Fig. 6-1, could be considered.

Installation in the RCM and LM-Lab. The optimum method for installing the IMBLMS in the two candidate carriers (RCM and LM-Lab) is by ground installation. A limited number of modules are possible; however, the major problem is the swept volume requirements of the major peripheral equipment, such as the LBNP and the ergometer. A pre-installed rack, that will permit the removal and replacement of individual modules is recommended. Such a rack can provide access to spacecraft power and communication. It will be mounted flat against the cabin walls to afford maximum cabin area for conduct of the experiments.

6.5.2 Handling and Transportability

To reduce the complexity of transporting the IMBLMS from the MDA to the OWS, a packaging arrangement was developed that will permit transferring single, double-, or four-module units. This approach reduces the mass/volume problem since the maximum four-module unit, with an envelope of 19.5 by 19.5 by 18 in., will weigh less than 150 lb.

Methods of handling the modules were examined, and the following basic techniques show promise:

- Dumbbell technique (tying two modules together by a common support joint)
- Shield strap technique (permiting hand and arm to be inserted through two straps, affording maximum leverage)
- Pistol grip (inserting pistol grip into structural provisions on the modules)
- Handle integral with the module but recessed

All four techniques can be employed in order to minimize the number of trips required to complete the installation from the MDA to the OWS. The recessed handle in the module permits easy removal and replacement modules during operation.

6.5.3 Module Interconnection and Interface Switching

The numerous sensor inputs and interconnects from peripheral equipment must be easily connected to the PBDM station modules. The analog/digital (A/D) tape recorder and the processor must have signal access to the various modules; in addition, many intramodule connections will be required. Only a few of these connections are permanent, and the various interconnecting lines can be efficiently shared by incorporating a switching network.

A tradeoff study, comparing manual versus automatic switching, indicated that an electronic switching system, controlled by the processor, is essential to the performance of these complex switching functions, and to the maintenance of astronaut tasks at a reasonable level. The electronic switching network will be controlled by commands from the processor, and will allow switching connection commands in the processor memory to be easily altered on the ground or on-orbit in order to satisfy changes in test philosophy and requirements.

Figure 6-6 shows the signal interface connections for the PBDM station. Each module requires a separate power connection and a few require water, vacuum, and air-pressure connections. The electronic switching network is included in the junction box to provide optimum switching capability with a minimum of module interconnections, and to allow later modification of planned experiments and switching network storage commands.

6.5.4 Calibration

On-board calibration equipment is required for the IMBLMS to verify satisfactory equipment operation. In addition, provision must be made for calibration during the important mission phases of prelaunch, in-flight operation, and reactivation.

Prelaunch calibration procedures will be consistent with preflight operations at KSC (Ref. 6-1). Two approaches have been analyzed: (1) ground calibration performed at

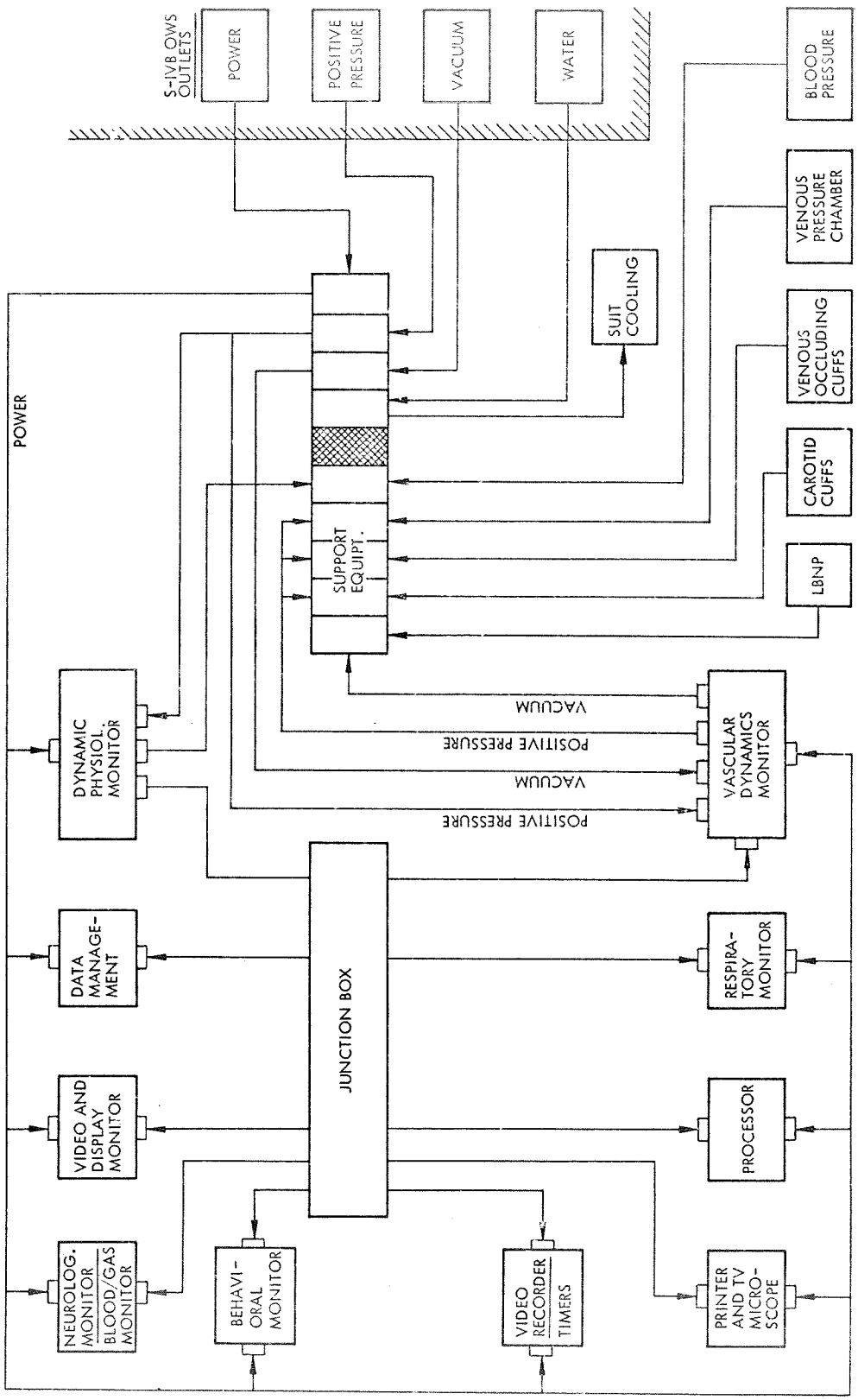


Fig. 6-6 Physiological/Behavioral/Data Management Interface and Distribution System

manufacturer's plant and system delivered to KSC in sealed condition, or (2) system assembled at KSC and system calibration runs performed. The latter approach is recommended as the IMBLMS is an integrated system and must be checked out with all peripheral equipment attached and operating.

The following four levels of calibration will be used for IMBLMS during in-flight calibration:

- Check for operation
- Qualitative calibration check
- Applied calibration
- Adjusted calibration

An example of the check for operation is the viewing of vectorcardiogram waveforms on the CRT. The qualitative calibration check will yield verification within ±10 percent of the exact measured value. The applied calibration check is designed to provide calibration information for modifying calibration factors or to generate new calibrations for application to the data. Adjusted calibration is intended to aid in adjusting equipment for proper operation. The three categories of calibration equipment required for IMBLMS are as follows:

- Transducer calibration. Accurately controlled and/or accurately measured sources of temperature, pressure, humidity, or other non-electrical quantities to be measured
- Electrical calibration equipment. Signal generator, voltmeter, calibration resistors, and appropriate connectors
- Special calibration equipment. Equipment items unique to a device, such as the mass spectrometer

6.5.5 Maintainability and Safety

In general, a remove-and-replace maintenance philosophy has been established for the IMBLMS. Modules, submodules, and critical components can be readily removed from the IMBLMS crew station with a minimum of time, astronaut skill, and training

requirements. This philosophy is based on information derived from LMSC studies of the type of operations and activities astronauts will have to perform while on orbit in relation to the amount of available time, training, skill levels, scheduled and unscheduled maintenance, housekeeping requirements, etc.

The following basic maintenance concepts will probably be applied to the primary Cluster systems:

- Fault isolation by automatic or semiautomatic checkout
- Restoration of subsystem to active status by module or submodule replacement
- Limited repair by manual method
- Limited system reverification by on-board equipment or by ground-based equipment through existing communication links

When considering maintenance on-board the cluster, allowance must be made for several constraints related to system and subsystem maintainability. One of the most critical involves available time versus required time. Another relates to safety considerations and protection of operating systems. Consideration must also be given to complexity of fault detection and isolation and the degree of corrective action, the complexity of systems/subsystems revalidation after maintenance, the skill level and training required of the astronaut, the degree of on-board maintenance capability, and the kind of special equipment being carried.

Crew time is a major constraint. During 1967, LMSC conducted a variety of complex computer programs related to on-orbit crew activities. Without exception, the computer runs indicated an overload of crew time.

On-orbit maintenance and safety are two major and interrelated aspects of the IMBLMS design. Identification, classification, and analysis of hazardous events constitute an integral part of the design effort. Cascading or internal module malfunctions are primarily the result of component failures, electrical overloads, short circuits, and

power supply surges. The IMBLMS design therefore will isolate the failure to the module concerned and, within the module, to the component in which the failure has occurred.

Several techniques have been considered for use in the IMBLMS design. Input and output lines will be protected against surge by active circuits to bypass temporary over-voltage conditions, particularly with respect to delicate circuits. Current-limiting circuits will be used to minimize damage to faulty circuits and prevent a severe drain on power sources. Isolation diodes will be used to prevent data loads from feeding spurious pulses back to their sources. Separate power leads isolated from signal leads will be provided for each module.

Maintenance requirements for the IMBLMS are as follows:

- Removal and replacement of critical items
- Replacement of loose connections and/or fittings
- Identification of failure points

The last requirement will be implemented by the integral calibration system for the IMBLMS. In addition, test reference points will be established for each module, thus permitting the astronaut using a voltmeter to identify the possible failure point in gross terms. This, in turn, will permit the ground station to recommend the best possible corrective action.

6.5.6 Electromagnetic Interference and Grounding Techniques

Requirements regarding electromagnetic interference (EMI) grounding technique as specified were reviewed and recommendations made for meeting these requirements in the IMBLMS design.

The dynamic physiologic monitor may be used in the CM where its d-c power will be obtained from the CSM. The grounding technique to be employed will implement the

spacecraft single-point ground requirement in its d-c power system and will avoid coupling of power-fault transients into the CSM grounding system.

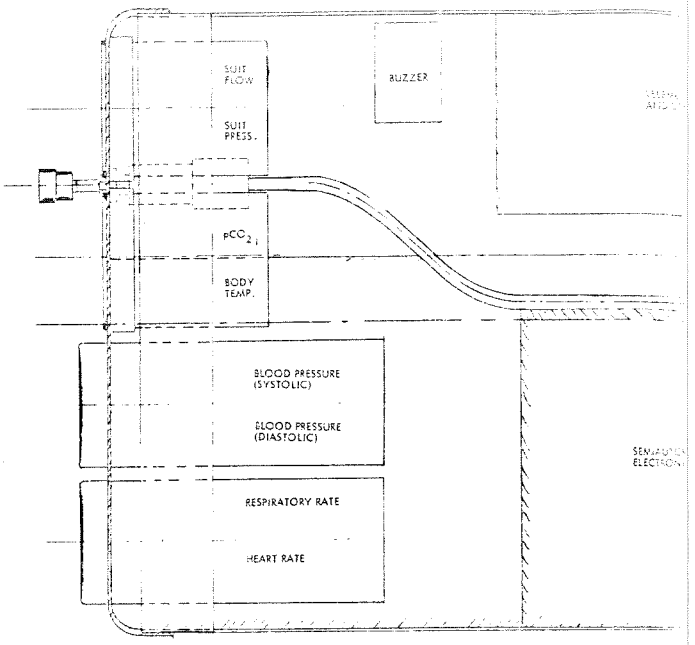
The two IMBLMS stations will have their primary power-input circuits isolated from all signal circuits, including returns. A separate portion of the junction box will be allocated for power distribution, and separate connector provisions will be made for the individual modules.

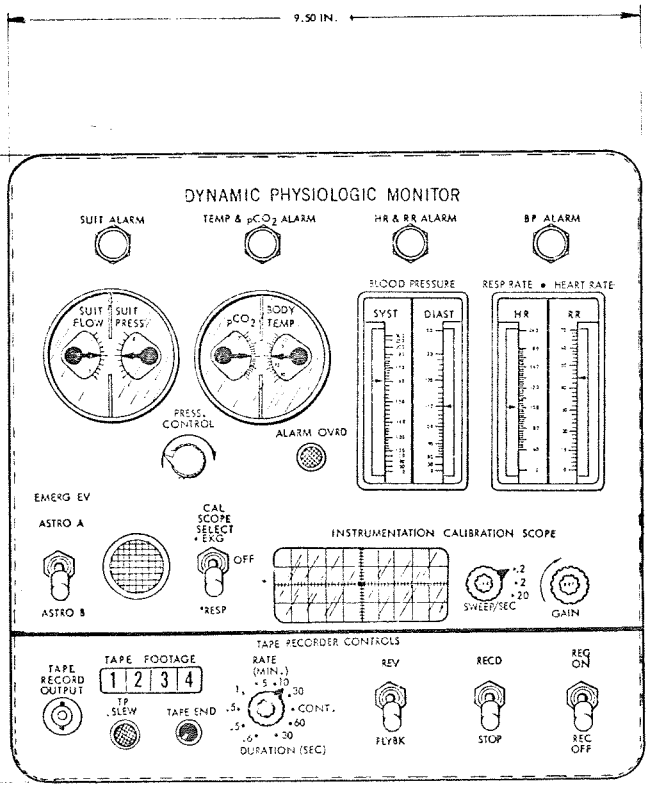
6.6 DYNAMIC PHYSIOLOGIC MONITOR

The dynamic physiologic monitor module shown in Fig. 6-7 was selected as a representative module and laid out in detail. The module structure consists, basically, of a machined base plate with provision for mounting the faceplate, the rear closure, and the module cover welded to it. Bracketry for mounting of black boxes and integrated circuits is included in the base plates. All black boxes within the module are located so as to be easily accessible and permit maintenance and be maintainable servicing without the removal of other boxes. The tape recorder, considered a critical item because its loss can mean loss of the total experiment results, is considered a submodule which can be easily removed and replaced. The rear closure of the module is provided with four bayonet-type electrical connectors and two quick-disconnect tube connectors. All connectors are recessed in the rear closure to permit the module to be placed on end without resulting damage to the connectors.

The module cover is a U-shaped sheet metal cap which fits over and is screwed to the face plate and the rear closure. The top of the cover is provided with a recessed handle, large enough to permit a gloved hand to grasp the handle bar without difficulty.

The exterior of the module is provided with rounded corners so that damage to space suits and injuries to crew members due to sharp edges can be eliminated. Equipment located on the face of module includes displays and controls. Equipment located behind the panel includes a tape recorder, instrumentation calibration scope, signal


SUIT FLOW
SUIT PRESS.
BUZZER
pCO_{2}
BODY TEMP.
BLOOD PRESSURE (SYSTOLIC)
BLOOD PRESSURE (DIASTOLIC)
RESPIRATORY RATE
HEART RATE


9.50 IN.
DYNAMIC PHYSIOLOGIC MONITOR
SUIT ALARM
TEMP & pCO_2 ALARM
HR & RR ALARM
BP ALARM
BLOOD PRESSURE
RESP RATE • HEART RATE
SYST
DIAST
HR
RR
SUIT FLOW
SUIT PRESS.
pCO_2
BODY TEMP
PRESS. CONTROL
ALARM OVRD
EMERG EV
ASTRO A
ASTRO B
CAL SCOPE SELECT • EXG
OFF
•RESP
INSTRUMENTATION CALIBRATION SCOPE
SWEEP/SEC
GAIN
TAPE RECORDER CONTROLS
TAPE RECORD OUTPUT
TAPE FOOTAGE
1 2 3 4
TP SLEW
TAPE END
RATE (MIN.)
DURATION (SEC)
REV
FLY BK
RECD
STOP
REC ON
REC OFF
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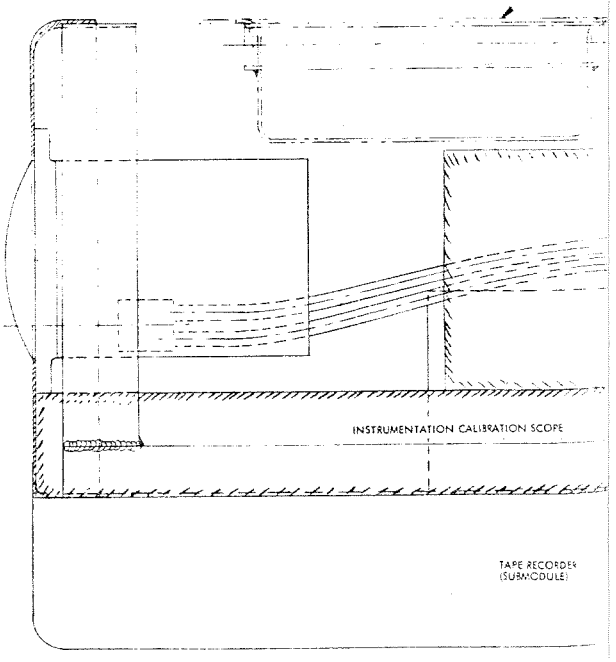
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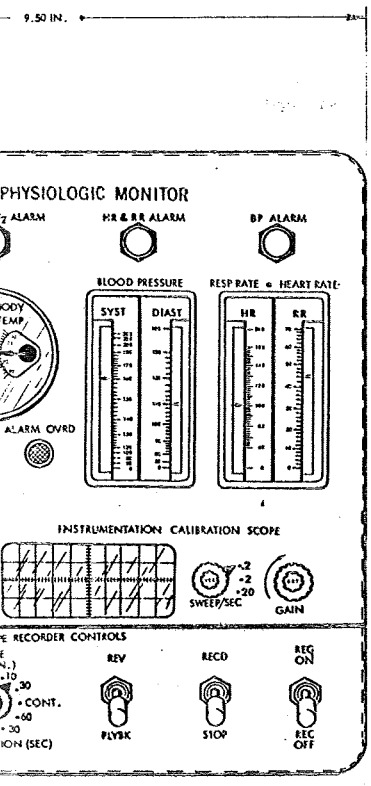
TAPE RECORDER (SUBMODULE)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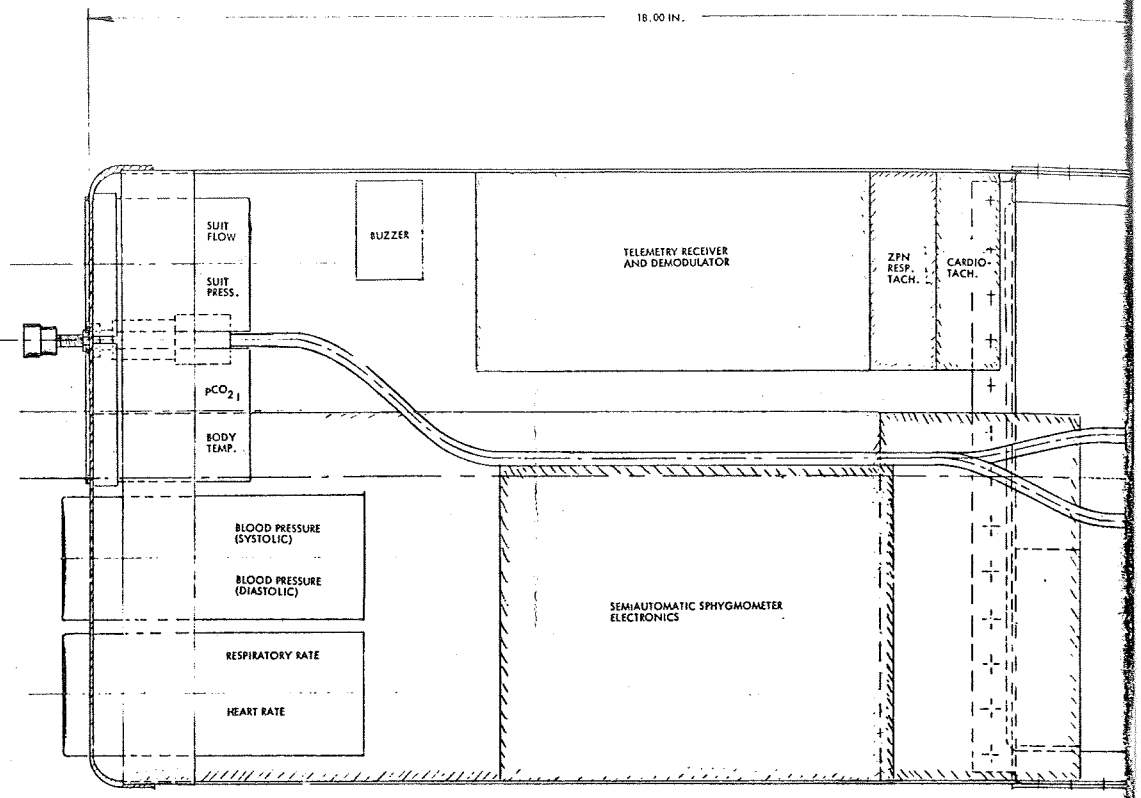
PHYSIOLOGIC MONITOR
HR & RR ALARM
BP ALARM
BLOOD PRESSURE
RESP RATE & HEART RATE
SYST
DIAST
HR
RR
ALARM OVRD
INSTRUMENTATION CALIBRATION SCOPE
SWEEP/SEC
GAIN
RECORDER CONTROLS
REV
RECD
REC ON
CONT.
PLYBK
STOP
REC OFF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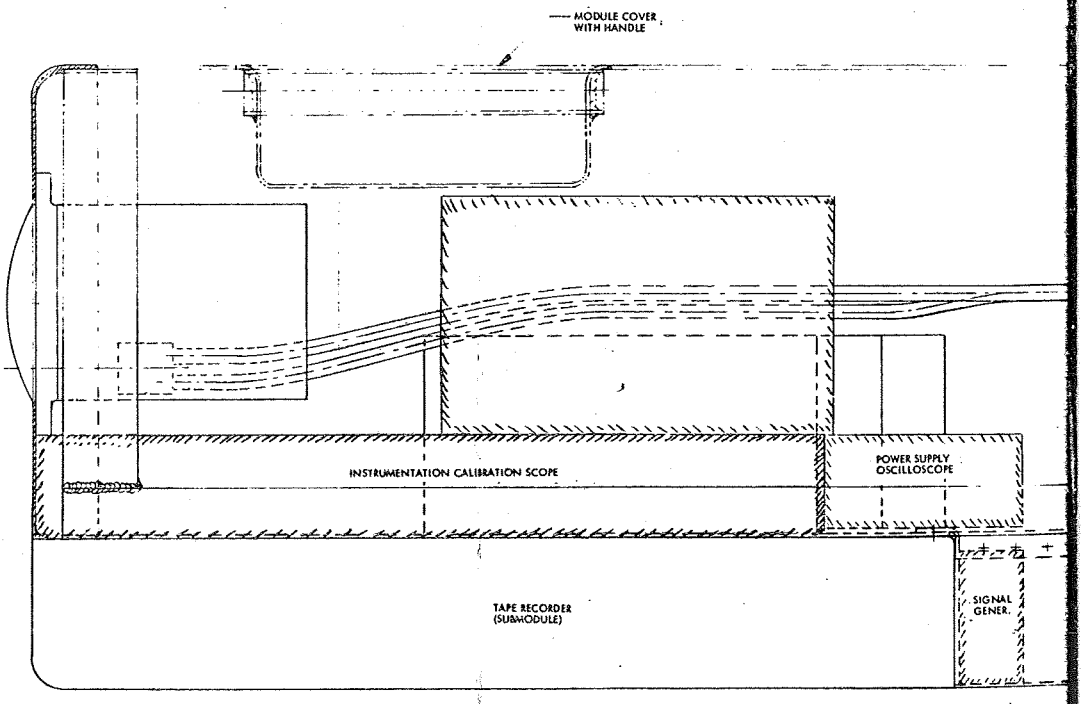
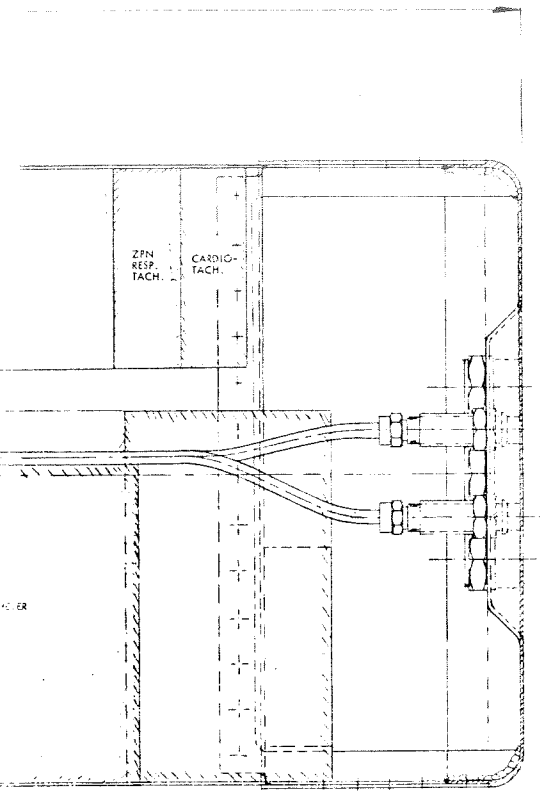
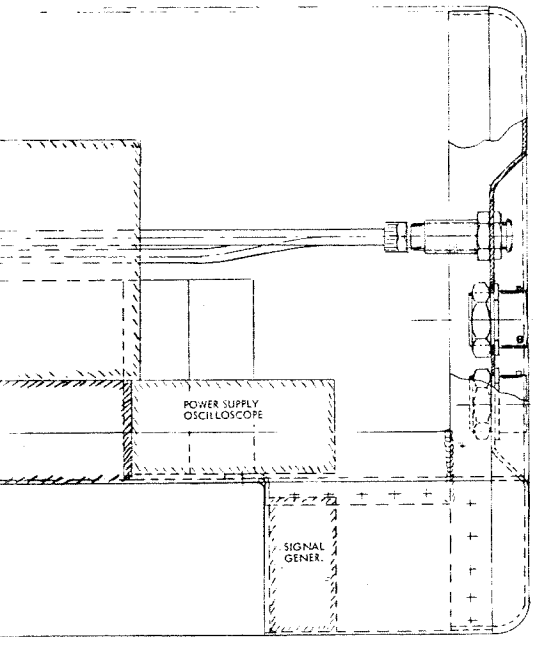
SUIT FLOW
SUIT PRESS.
BUZZER
TELEMETRY RECEIVER AND DEMODULATOR
ZPN RESP. TACH.
CARDIO-TACH.
pCO_2
BODY TEMP.
BLOOD PRESSURE (SYSTOLIC)
BLOOD PRESSURE (DIASTOLIC)
SEMIAUTOMATIC SPHYGMOMETER ELECTRONICS
RESPIRATORY RATE
HEART RATE


MODULE COVER WITH HANDLE
INSTRUMENTATION CALIBRATION SCOPE
POWER SUPPLY OSCILLOSCOPE
TAPE RECORDER (SUBMODULE)
SIGNAL GENER.





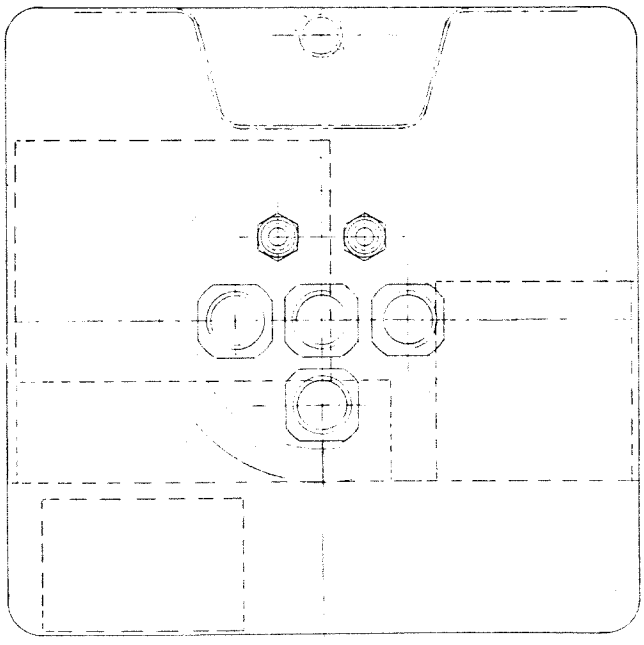


Fig. 6-7 Dynamic Physiologic Monitor

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generator for calibration, cardiotachometer, respirotachometer, pressure regulator for semiautomatic blood pressure, and TM receiver and demodulator for EVA and rotary chair near-field telemetry. The total weight of the module is 50 lb.

6.7 IMBLMS MODULES

Thirteen modules make up the complete PBDM station, and the complete Biochemical station consists of eight modules. A safety or clinical monitoring capability and include two modules from the PBDM station and three modules from the Biochemical station, plus a small storage module. The five data management modules can be combined with various other modules incrementally to increase total capability.

6.7.1 Support Equipment

This module is a double-sided standard module. It provides the storage space required for such support equipment as blood-pressure cuffs, a 12-point thermistor harness, paste, electrodes, an impedance cardiograph, and the limb electrodes. The remaining space represents a growth potential in stowage capability for support equipment.

6.7.2 Interface and Distribution System

This package, measuring 9.5 by 19 by 19 in., is a double-size module and performs the important function of interfacing with the subject, the on-board power, water, vacuum, and the positive pressure system. The module contains a vectorcardiogram vest, an impedance pneumogram (ZPN) vest, an electrocardiogram vest, oral/ear temperature sensors, a phono- and vibro-cardiogram harness and microphone, a flowmeter, an ear oximeter kit, and respiratory masks and hoses. All these items provide the interface with the subject. Four separate compartments within the module are utilized to provide the distribution of the power, water, vacuum and positive pressure from the board system to the appropriate IMBLMS modules.

6.7.3 Junction Box

The junction box (J-box) is a double-size standard module which functions as the central unit in the PBDM through which all the signals are routed. It contains the electronic switching network which is controlled by commands from the processor and will allow an efficient sharing of the various interconnecting lines between the modules.

6.7.4 Data Management Modules

Five data management modules are required for the IMBLMS. These are the video and display monitor, video recorder and timers, manual data entry (including the memo recorder) printer, and processor. The functions and equipment characteristics of each module have been discussed in Section 5.

6.7.5 Dynamic Physiologic Monitor

This module is the most versatile of those in the IMBLMS, and can be removed from the PBDM station and transported to remote sites such as the CM, LM, or AM. It is capable of obtaining standard physiological measurements (body temperature, heart rate, respiration rate, and blood pressure) and major, critical, pressure-suit measurements (suit flow and pressure, and pCO_2). End-instrument calibration is provided, using a signal generator with display on a miniature CRT. Calibration scope selector is provided for all measurements. A tape recorder is included in this module as a submodular component.

6.7.6 Behavioral Monitor

This monitor has been designed to provide measurement capability for visual, psychomotor, and auditory functions. A manual tracking task is used for evaluation of combined vestibular and psychomotor capabilities. The task display appears on a

CRT housed in one of the data management modules. A vision tester is housed in a storage compartment. The sensitivity of the subject to auditory stimuli is measured with a prerecorded tape, using an audio memo-tape recorder. Psychomotor functioning is evaluated by means of a combination of simple response buttons.

6.7.7 Neurological Monitor

This module performs two completely separate functions. The upper part is designed to accomplish the vestibular measurements specified for the AAP, and the lower part monitors the amount of oxygen and CO_2 in the blood contained in the capillaries as well as the measurement of the hydrogen ion concentration in the blood.

The upper part of the module contains controls for the rotating litter chair, as well as the tachometer, accelerometer, and timers. The lower part of the module has two dual meters for respiratory gases and two for blood gases.

6.7.8 Vascular Dynamics

The vascular dynamics module is structured primarily to support peripheral measurements requiring relatively large equipment (e.g., the LBNP, ergometer, and countermeasure devices) and to support associated measurements being taken while using this equipment. Timers are provided for measurements requiring specific measurement time periods. All controls and monitoring of the measurements are to be regulated by an observer because of the stress level imposed on the subject.

6.7.9 Respiratory Monitor

This module has been designed to analyze the respiratory system. For this purpose, pressure gauges to measure $O_2$34, $O_2$32, pN_2, pH_2O, and pCO_2 and gauges to measure volume and flow rate are provided on the face of the panel. Environmental conditions, such as cabin pressure, humidity, and temperature are displayed, and controls have been installed on the same panel.

6.7.10 Biochemical Analyzer 1

This module is used for colorimetric, microscopic, and hematocrit analysis. It contains a colorimeter designed to accept plastic reaction bags and equipped with a wavelength selector, an on/off switch, a zero-adjust, and 100-percent adjust controls. The module also contains a distilled-water dispensing unit; a dual meter; a vacuum port; and a hematocrit unit, consisting of a conductivity measuring instrument, two electrodes to connect a blood capillary, an on/off switch, a zero-adjust and 100-percent adjust controls.

6.7.11 Biochemical Analyzer 2

This unit is used to perform electrophoresis analysis, to determine the O_2 and CO_2 values in capillary blood, and to measure Na, K, Cl, and pH in urine or serum. For this purpose, the module contains an electrophoresis power supply with a timer that turns off the power supply at the specified time; an O_2-CO_2 electrode assembly; an Na, K, Cl, and pH electrode assembly; two selector switches; and a dual meter.

6.7.12 Isotope Monitor

This module houses a scintillation counter used in radioisotope trace determinations. A well crystal and spectrometer are used in determining equilibrium concentrations of Chromium 51 and Iodine 125 (if used for the IMBLMS) and in the in vitro partition of I-131, labeled triiodothyronine (T_3).

6.7.13 Incubator

The incubator is used for bacteriology studies, immunodiffusion studies, and blood clotting. It is equipped with a temperature control and thermometer. Because of the relatively small internal volume required, a large volume is available for insulation. This feature, coupled with the frequency of incubator use, suggests that the module be in continuous operation throughout the mission, thus allowing omission of on/off switch function and thereby increasing reliability.

6.7.14 Biochemical Waste Collection Compartment

This module is designed to provide the necessary storage volume for waste products, such as used reagent, water, urine, and blood which must be flushed from measuring devices. If required, plastic bags with desiccants will be used.

6.7.15 Supply Storage and Centrifuge, and Spare Module

The supply storage and centrifuge module measures 19 by 19 by 9.5 in. and is physically divided into two sections, each measuring 19 by 19 by 4.75 in. These two sections are joined by a hinge along one of their 19-in. sides. The other section contains the centrifuge which is designed to separate four blood samples into plasma and blood cells within 10 min. Speed controls are located on the section external surface, and a safety interlock prevents the centrifuge door from being opened while the device is in motion.

The spare module provides growth capability and can be used to store additional equipment as it is developed, or to store additional supplies. This module can also prove useful for storing waste material accumulated during one test day. In this case, the waste material could be transferred to the waste disposal module after testing is completed.

6.7.16 Freezer Module

The requirement for storing body and waste fluids for on-board or postflight analysis are met by a cryogenic fluid in a freezer unit, which operates in a temperature range of -75° to 100°C. The fluid or gas, which fills all the void space around the specimen containers, is solidified by being subjected to a vacuum before launch. The temperature of the solidified gas is controlled by vapor pressure with a pressure relief valve.

Insulation is provided over the surface of the unit. Associated equipment to be used with the freezer unit is a urine-volume measurement system modified to permit extraction of aliquots of urine. A liquid-gas phase separator and a transfer system must also be used to transfer samples to freezer, reagent bags, or slides.

6.8 SUMMARY OF IMBLMS EQUIPMENT

Based on the preliminary design concept of the IMBLMS and approved biomedical experiments on AAP, a preliminary equipment list (Table 6-1) has been developed. This list shows that a comprehensive biomedical measurement system requires 977 lb of equipment. Volumetric requirements for equipment storage are as follows:

Equipment	Volume (ft^3)
PBDM (13 modules)	15.3
Biochemical (8 modules)	5.9
Major Peripheral Equipment	
LBNP	2.4
Ergometer	2
Total body exercise system	2.3
Body mass measurement system	14.0
Specimen mass measurement (2)	0.6
Rotating chair	12
Pulmonary equipment	4.5
Total	59

Table 6-1

PRELIMINARY EQUIPMENT LIST

Module/Equipment	Weight (lb)
PBDM	(396)
Dynamic Physiologic Monitor	36
Vascular Monitor	21
Neurological/Blood-Gas Monitors	13
Respiratory Monitor	55
Behavioral Monitor	15
Junction Box	14
Interface and Distribution System	36
Support Equipment	44
Printer/TV Microscope Module	54
Processor	25
Memo-Recorder/Manual Data Entry	18
Video and Display Monitor	29
Video Recorder and Timers	
Video Recorder	25
Timer Display	11
Biochemical	(235)
Biochemical Analyzer 1	25
Biochemical Analyzer 2	17
Isotope Monitor	85
Freezer	26
Incubator	6
Supply Storage and Centrifuge	62
Spare Module	7
Biochemical Waste Collection Compartment	7
Major Peripheral Equipment and Supplies	(346)
LBNP	20
Ergometer	35
Total Body Exercise System	25
Body Mass Measurement System	38
Specimen Mass Measurement System (2)	28
Rotating Litter Chair and Associated Equipment	140
Pulmonary Equipment	60
Total	977

6.9 DEVELOPMENT STATUS

Four categories were esgablished to summarize the IMBLMS hardware development status. These are (A) Qualified for manned spaceflight, (B) Under development for manned spaceflight, (C) Laboratory or commercial, and (D) Conceptual and/or research. Table 6-2 presents this information together with potential sources and estimated procurement lead times. Sixty-four major items were investigated together with such minor equipment as display meters, and connectors. Thirty-one of the major items are in Category C, 13 are in Category B, 12 are in Category A, and eight are in Category D. Many minor equipment items are included in Category A (e.g., Apollo-type display meters are applicable to the IMBLMS modules). Lead-time is, in general, directly connected to the category. Longer lead-times are associated with the conceptual/research type of equipment.

6.10 JUSTIFICATION FOR AAP CLUSTER

The effective utilization of a comprehensive biomedical flight laboratory such as the IMBLMS imposes unique requirements on an orbital space station. Vehicular systems reliability for 1-yr missions, facilities to accommodate multiple crews, intermittent rendezvous for crew exchange and payload return, and adequate spacecraft volume and power capabilities to sustain an extensive measurement program in many scientific areas are essential for a cost-effective, space-research program. The AAP Cluster provides these capabilities.

A comparison of the candidate spacecraft and their compatibility with the IMBLMS is presented in Table 6-3. An important justification for the AAP Cluster is its growth capability. The direction and requirements of a research program such as the AAP can be expected to change with the accumulation of space experience. Even the degree of comprehensive planning that has characterized the IMBLMS Program, for example, can reduce but not fully eliminate program redirection. Because of the lead times required for the development of flight systems, the growth capability of the AAP Cluster is essential to expedite the research goals of the IMBLMS and other scientific programs.

Module	Measurement	Major Equipment Item	Source	Status[a]	Lead Time (mo)
Physiologic Monitor	Core (ear) temperature	Transducer and signal conditioner	GFE	A	4
	Arterial blood pressure (systolic and diastolic)	Automated sphygmometer	GFE	B	8
	Heart rate	Cardiotachometer (using ECG I)	Spacelabs, Inc.	B	12
	ECG	ECG	GFE	A	4
	Instrument data recording	Analog and digital tape recorder	[b]	C	11
	Instrument calibration	Calibration oscilloscope with power supply	[b]	C	15
	Skin temperature	12-thermistors and signal conditioner	GFE	A	4
	Respiratory waveform	ZPG	GFE	A	4
	Respiratory rate	ZPG and respirotachometer	GFE	C	12
Vascular Monitor	Response to LBNP	LBNP device	Melpar	B	6
	Response to exercise	Ergometer	NASA RFP	C	8
	VCG	Frank lead VCG	GFE	A	4
	Vb CG PCG	Vibrocardiogram and Phonocardiogram	GFE	B	8
	BCG	Ballistocardiogram	Spacelabs, Inc.	C	12
	Thoracic blood flow	Measurement system	GFE	D	16
	Cardiac output	Kubicek impedance cardiogram	Spacelabs, Inc.	A	4
	Central venous pressure	Jugular vein transducer and amplifier	Biosystems, Inc.	D	12
	Peripheral venous pressure	Transducer and amplifier	Biosystems, Inc.	D	12
	Regional blood flow	Shell device for limb	Biosystems, Inc.	D	21
	Venous compliance	Limb plethysmograph	Spacelabs, Inc.	C	12
	Arterial pulse contour	Transducer and signal conditioner	Spacelabs, Inc.	D	18
	Response to carotid stimulation	Carotid collar and controls	LMSC	D	21
	Respiratory waveform	Impedance pneumograph	Spacelabs, Inc.	A	4
Respiratory Monitor	Lung volumes O_2 consumption	Integrating flowmeter	GFE	C	12
	Gas analysis	Mass spectrometer	GFE	B	12
	Lung compliance Airway resistance	Pressure transducer, flowmeters, and mask	Spacelabs, Inc.	C	12
Blood/Gas Monitor	Capillary blood O_2 and CO_2	Specific ion electrodes	Beckman Instruments, Inc.	C	14
	Blood pH	Specific ion electrodes	Beckman Instruments, Inc.	C	14
	Arterial oxygen	Ear oximeter	Spacelabs, Inc.	C	12
Neurological Monitor	Human vestibular function (M131)	Rotating litter chair and associated equipment	John Hopkins	C	18
	Nystagmus	ENG	Spacelabs, Inc.	B	8
	Ocular counter-rolling	EOG	Spacelabs, Inc.	B	12
	Sleep analysis	EEG	GFE	A	4
	Diagnostic tests	Neuro kit	GFE	A	0

(a) Status definitions
A – Qualified for manned spaceflight
B – Under development for manned spaceflight
C – Laboratory or commercial
D – Conceptual or research
(b) Not yet selected

Module	Measurement	Major Equipment Item	Source	Status[a]	Lead Time (mo)
Neurological Monitor(Ctd)	Visual/psycho-motor testing	Oscilloscope target and control stick	(b)	D	20
	Eye motions	High-speed cine' camera on biteboard	(b)	B	10
Behavioral Monitor	Vision	Special vision test equipment	NASA (Ames)	D	24
	Audibility	Audiometer	LMSC	C	18
		Earphones which exclude external sound	(b)	C	12
	Psychomotor	Two-axis controller (proportional)	LMSC	C	18
	Response	Use of equipment located in other modules (e.g., TV microscope, computer)	–	–	–
Video and Display Monitor	TV monitor and analog/digital displays	Cathode ray oscilloscope	(b)	C	15
Video Recorder and Timers	Display of event and mission elapsed time	Numerical display	Apollo type unit	A	4
	Recording of urine and blood micro-scope pictures	Videotape recorder	(b)	C	11
Printer	Urine and blood analysis	Microscope	NIKON	B	4
	Urine and blood analysis	TV camera	(b)	C	6
	Printed record of data	Printer	Clary Corp.	B	6
Processor	Enter data	Keyboard and display	Apollo Type unit	B	6
	Data processing	Multiplexer, A/D, D/A, digital computer	LMSC	C	12
Memo-Recorder/ Manual Data Entry	Record verbal comments	Audio tape recorder	(b)	C	11
	Enter numerical data for processing	Thumbwheel switches and circuits	Daven Co.	A	6
Biochemical Analyzer 1	Blood and urine	Colorimeter	Beckman Instruments, Inc.	C	20
	Blood	Hemotacrit		C	11
Biochemical Analyzer 2	Blood analysis	Electrophoresis unit		C	20
	Blood and urine K, Na, Cl, pH	Specific ion electrodes		C	14
Incubator	Microbiology and Immunology	Incubator and test plates		C	14
Supply Storage and Centrifuge	Blood and urine	Centrifuge and sample handling		C	14
	Various types	Expendable supplies for 3 men, 56 days		C	20
Spare	Microbiological, blood, and urine	Microscope and accessory items		C	14
	Urine specific gravity and osmolarity	Refractometer		C	10
Isotope Monitor	Radioactive tracers in blood	Radioisotope counter	(b)	D	24
Freezer	Blood and urine preservation	Freezer	LMSC	C	21
Biochemical Waste Collection Compartment	Waste disposal	Mechanical and solenoid valves	(b)	C	10

Peripheral Equipment	Measurement	Major Equipment Item	Source	Status [a]	Lead Time (mo)
Body Mass Measurement System	Weighing of astronauts	Body mass measurement device	USAF, AMD	B	8
Specimen Mass Measurement System	Weighing of specimens	Specimen mass measurement device	USAF, AMD	B	8
Total Body Exercise System	Exercise	Exercise device	USAF, AMD	B	8

Table 6-2 Equipment Status

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Table 6-3

AAP CANDIDATE CARRIER COMPARISON

Aspect	RCM	LM-LAB	LM-ATM	MDA	S-IVB (Wet)	S-IVB (Dry)
Measurement Comprehensiveness	Limited	Limited	Limited	Fair	Excellent	Excellent
Volume (ft^3)	360	247	1-2	800	1300	4, 260
Mission Capabilities						
Crew Size	2	2	1	2	3-6	6-9
Mission Duration	56 days	56 days	56 days	56 days	1 year (resupply)	1 year
Operation	Limited	Limited	Poor	Good	Good	Excellent
Reliability	Fair	Fair	Fair	Fair	Good	Excellent
Maintainability	Limited	Limited	Poor	Limited	Excellent	Excellent
Spacecraft Support	Limited	Limited	Poor	Fair	Good	Excellent
Growth	Poor	Poor	None	Fair	Excellent	Excellent

6-32

The minimal skills and number of crew members required for an optional biomedical program is dependent on an evaluation of future space experience. The crew size for the AAP Cluster can easily be expanded from three to six to nine if required, thereby permitting a wider range of on-board skills and experimental subjects. The large number of concurrent experimental objectives identified for the AAP Cluster will require extended manned space operations, thus ensuring the development of an adequate data base of man's spaceflight performance.

The AAP Cluster has adequate volume for the conduct of experiments in addition to reasonable living quarters for multiple crew members. IMBLMS volume requirements encompass leased space for measurement equipment, controls and displays, and recording equipment, together with the swept volume needed to conduct provocative and continuous testing (e.g., in using the LBNP, ergometer and rotating chair). Unlike many of the scientific and engineering experiments, space for both an experimenter and astronaut-subject will be required for performance of some of the biomedical measurements.

The IMBLMS interfaces with spacecraft systems are extensive. Requirements exist for power, communications, life support, waste management and data handling. A separate filtered compartment is desirable for the biochemical station in the event that liquid escapes during specimen measurement. Expendable requirements, especially for larger crews and longer missions, are sizable, necessitating frequent resupply for spacecraft systems smaller than the AAP Cluster.

Expendables for the AAP Cluster can be supplied during rendezvous scheduled for crew exchange (to provide incremental reentry and postlanding performance evaluation) and for the return of preserved biological specimens and experimental film.

The principal advantage of the dry-launch S-IVB is increased reliability. A preliminary analysis indicates that the IMBLMS concept can be integrated into the configuration with a minimum of modification. Modular packaging will be retained along with the cockpit wrap-around design. The major advantages of this configuration are as follows:

- Increased reliability
- Complete prelaunch checkout
- Elimination of MDA installation problems
- Minimal on-orbit transportability problems

Weight savings are not substantial (3 to 5 percent) since the major reduction occurs in the module-carrying frames used in transporting the IMBLMS from the MDA to the OWS.

Ground installation would permit the design of a completely fixed station. The fixed station has slight advantages over the modular station in terms of weight, volume, and cost which are essentially offset by the ease of operation and maintainability of the modular station. Reliability is considered essentially equivalent for the two stations. A fixed station is not recommended for the IMBLMS, however, since it will not provide the versatility, experiment and spacecraft flexibility, or growth/substitution capability of the modular station.

Section 7
PHASE C DESIGN AND PHASE D DEVELOPMENT AND OPERATIONS

Lockheed Missiles & Space Company has participated in the first two phases of the IMBLMS Program – Phase A – Advanced Studies (Biolabs), completed in 1966, and IMBLMS Phase B, Section I, completed in October 1967. (See Refs. 1-2 and 2-1.)

At the conclusion of the Phase B, Section I work, LMSC submitted a proposal on the IMBLMS, Phase C – an 8-month design effort (Ref. 1-3). Subsequently, NASA-Headquarters authorized LMSC to fulfill a Phase B, Section II, Supplemental Agreement to the original Phase B contract.

During the extension period, 4 Dec 1967 to 16 Feb 1968, LMSC made significant strides in refining measurement/equipment, the modular concept, station layout, data management, and system engineering.

No significant changes are recommended for the Phase C proposal although relatively greater emphasis will be placed on the behavioral and biochemical elements consistent with NASA guidance since major emphasis was placed on the physiology element during the Phase B, Section II effort.

In reviewing the Phase C schedule, (Fig. 7-1), the time spans indicated are still considered reasonable; however, it must be recognized that long, drawn-out uncertainties in Task 1 (Identify Measurement Requirements) and Task 2 (Define Measurement Equipment Modules Requirements) would seriously jeopardize the engineering design schedule. Consequently, the major output from these two Phase C tasks must be completed and available to design personnel 60 days after Phase C go-ahead. In addition, the NASA-supplied GFE list, and carrier and mission definitions, should be firmed up and established by mutual agreement at the start of Phase C or, at the latest, 30 days after Phase C go-ahead, in order to maintain the basic schedule presented.

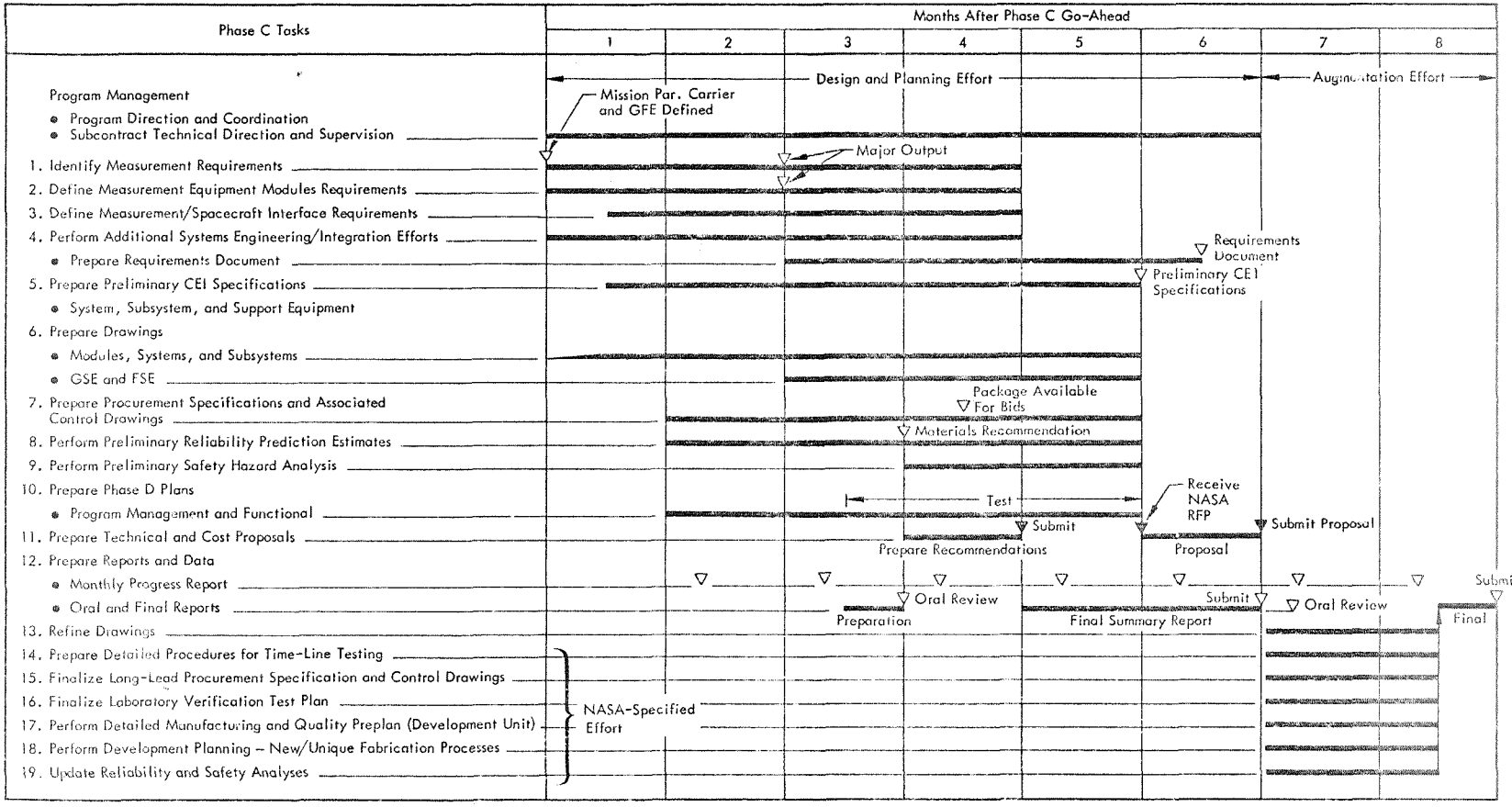


Fig. 7-1 Schedule for Phase C

In the schedule for Phase D, as shown in Fig. 7-2, the training unit presented in this schedule under the Phase C proposal (Ref. 1-3) has been expanded, by verbal NASA direction, to include a neutral buoyancy unit and part-task trainers (subassemblies), as well as the complete flight trainer.

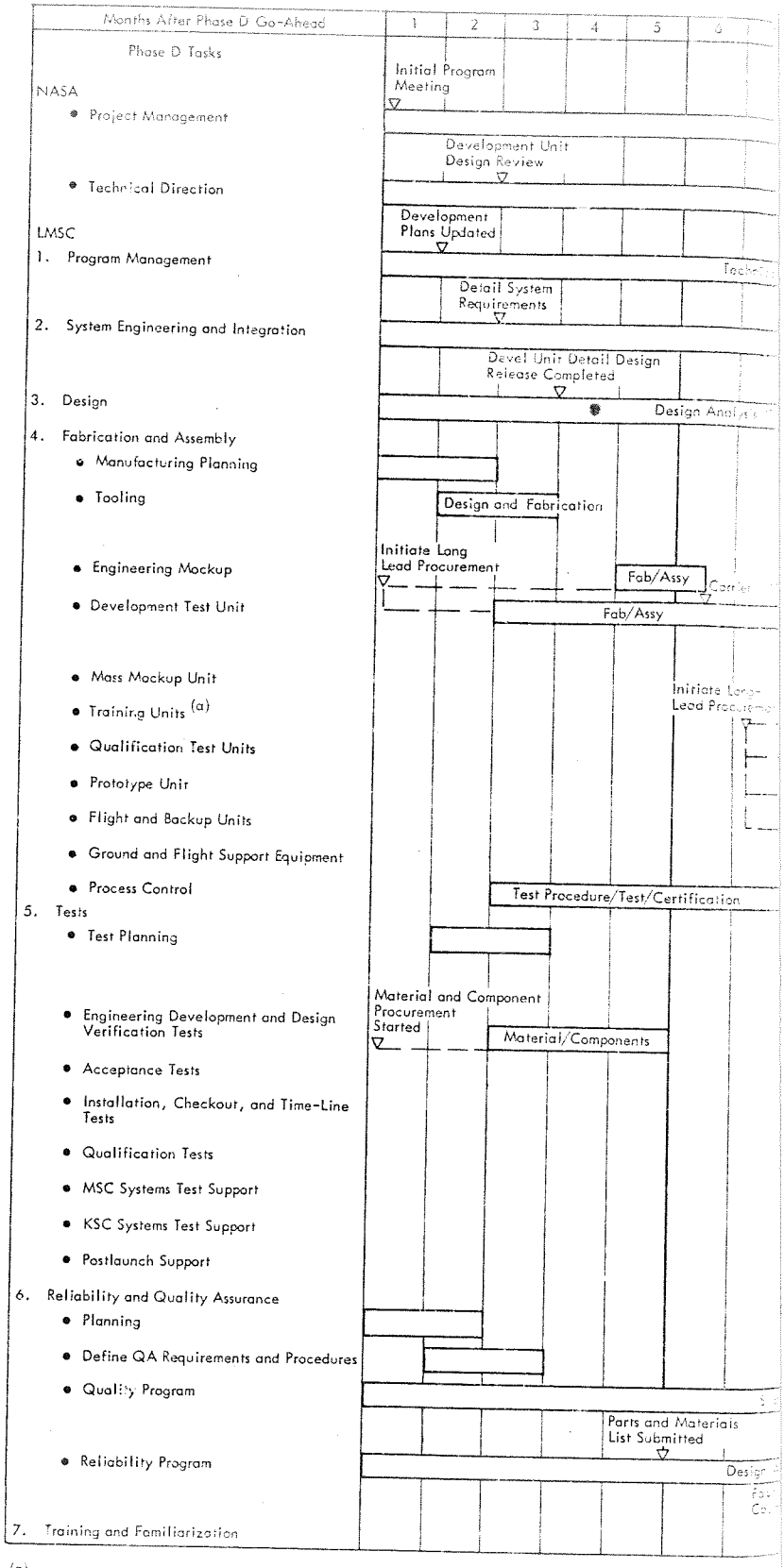
The prototype unit, originally planned as a flight-type unit for in-house use in resolving integration and GFE interface problems, is still recommended. It can be used as backup for the Training Program or as a spare system for the Qualification Test Program.

The two IMBLMS Qualification Test Program units are identical to the flight hardware and are to be used for environmental testing. However, it is a basic ground rule that hardware used for qualification testing should not be flown because of possible over-stress and reliability degradation occurring during the testing process; hence, the qualification test units should not be considered as flight hardware backup. The 4-month time-span allocated in the Phase D schedule for qualification testing (Fig. 7-2) therefore assumes the need for two qualification units in order to perform critical tests in parallel, although both units will not necessarily be subjected to identical tests.

The use of only one qualification unit will extend this test schedule by 2 to 3 months with a resultant equivalent slippage in the flight schedule. Further, if a failure should occur with only one unit available for the test program, a much greater slippage could result. It is strongly recommended that two qualification test units be procured and that major support be afforded this portion of the test program.

The original Phase D schedule allowed for a time span of 4 to 6 months between the delivery of flight hardware and first launch. This time span is consistent with Lockheed experience on many successful NASA and Air Force space efforts. However, recent verbal direction from NASA-Headquarters requests a 9-month lead time between flight hardware and launch. The revised schedule therefore shows the hardware deliveries occurring 8 to 10 months (at 1 month intervals) prior to launch, which extends the total Phase D program – from contract go-ahead to launch – to 29 months compared to the originally proposed 25-month program.

Adherence to the foregoing Phase C and D schedules will permit an IMBLMS flight in mid-1971 and thereby provide NASA and the scientific community with its first opportunity for a comprehensive evaluation of man's performance during extended spaceflight.



(a) Includes Flight, Neutral Buoyancy, and Part-Task

(b) Prototype Unit for use as Training Unit backup or retained as Qualification Unit backup

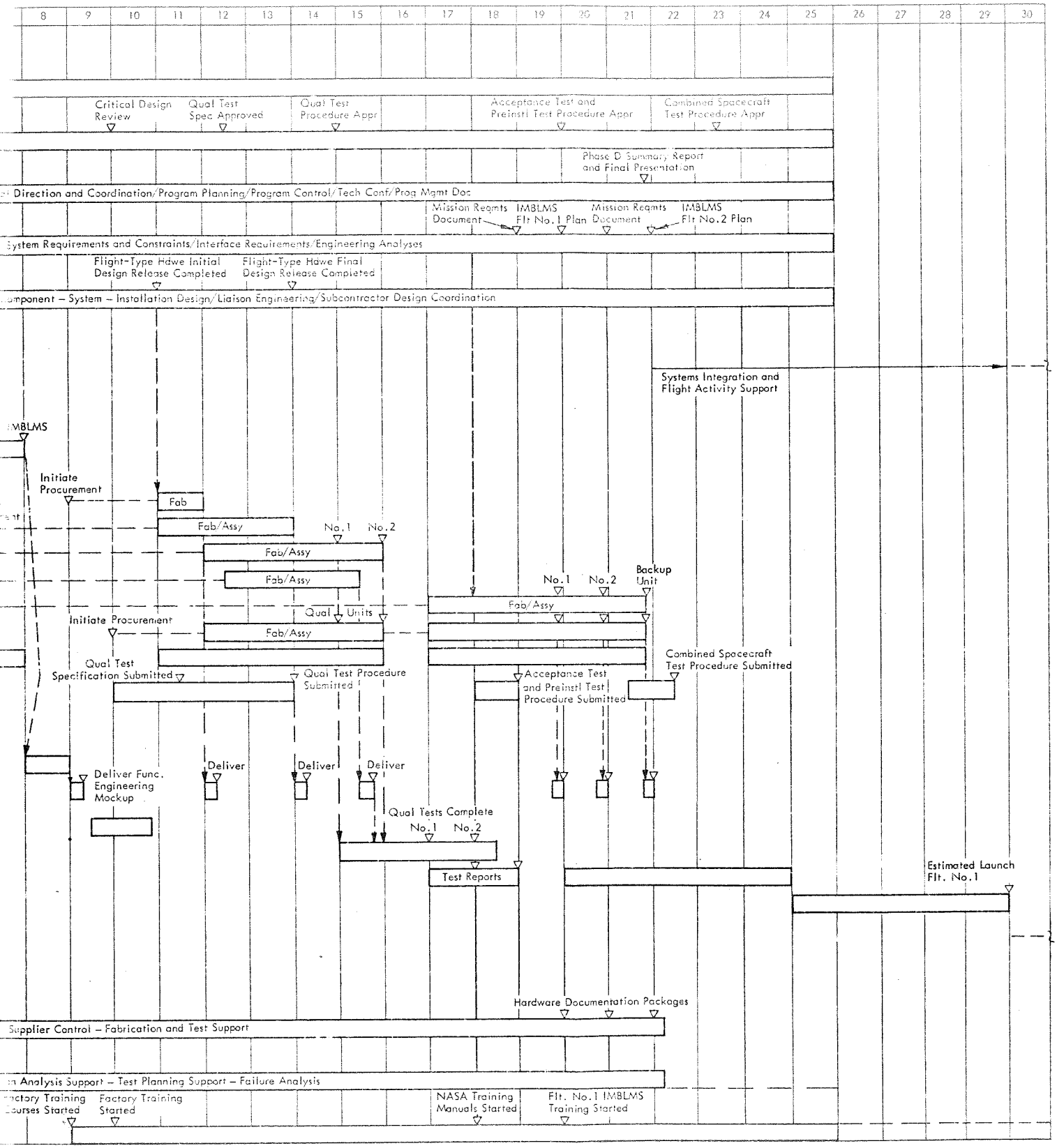


Fig. 7-2 Schedule for Phase D

Section 8
REFERENCES

1-1 National Aeronautics and Space Administration, Design and Development of an Integrated Medical and Behavioral Laboratory Measurement System, NASA RFP 10-1243, Washington, D.C., 27 Dec 1966

1-2 Lockheed Missiles & Space Company, Biological Measurement of Man in Space, Vols. I – V (NASA Contract NASw-1071) M-61-64-1, 1964–1966

1-3 -----, Proposal for Integrated Medical and Behavioral Laboratory Measurement System, LMSC-699289, Sunnyvale, Calif., 27 Oct 1967

2-1 -----, Integrated Medical and Behavioral Laboratory Measurement System, Phase B, Final Report, T-30-67-1A, Sunnyvale, Calif., 27 Oct 1967

2-2 USAF, Aerospace Medical Research Laboratories, General Description and Evaluation of an On-Line Oxygen Uptake Computer, by A. T. Kissen, D. W. McGuire, and J. J. Sterling, AMRL-67-17, Wright-Patterson Air Force Base, Ohio, Jun 1967

2-3 National Aeronautics and Space Administration, A Code Transformation Task that Provides Performance Measures of Nonverbal Mediation (COTRAN), by E. A. Alluisi and G. Coates (University of Louisville), NASA CR-895, Louisville, Ky., Sep 1967

3-1 Lockheed Missiles & Space Company, Biological Measurement of Man in Space, Vol. VI: Time-Line and Feasibility Analysis for AAP Biomedical Experiment Program, Final Report, M-61-64-1-VI. Sunnyvale, Calif., Jan 1966 (NASA Contract NASw-1071, Modification 3)

6-1 National Aeronautics and Space Administration, Kennedy Spacecraft Center, Spacecraft Operations Directorate, 990-26-0001, 7 Mar 1967

6-2 MIL-STD-461, Electromagnetics Interference, Characteristics, Requirements, and Equipment